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THE ECOLOGY AND HABITAT USE OF THE NORTHWESTERN
POND TURTLE (*CLEMmys MARMORATA MARMORATA*)
IN A LAKE IN SOUTHWESTERN OREGON

by

LAURA L. TODD

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
BIOLOGY

Portland State University
1998

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ABSTRACT

An abstract of the thesis of Laura L. Todd for the Master of Science in Biology presented December 4, 1998.

Title: The Ecology and Habitat Use of the Northwestern Pond Turtle (*Clemmys marmorata marmorata*) in a Lake in Southwestern Oregon

Few studies have addressed the biology of northwestern pond turtles in relatively undisturbed stillwater habitats. This study details data obtained over six years on the northwestern pond turtle at Carmine Lake, Douglas County, Oregon. Study foci were basking patterns, mark-recapture, active-season movements, and habitat use and characterization.

Visual observations of basking turtles showed that turtles basked more than expected under the following conditions: 1) at 1000 hr; 2) air temperatures of 20-25°C; 3) low wind speeds[0-6 kph (0-3 mph)]; and 4) no precipitation. Emergent basking occurred more frequently than water basking under all conditions.

Growth rates were calculated for juveniles (<110 mm), subadults (110-135 mm), and adults (> 135 mm), and for adult males and females. Growth rate corresponded closely to visually observed life stages of western pond turtles. Juveniles grew most rapidly; subadults, regardless of appearance of secondary sexual characteristics, grew at

moderate rates; and adults grew most slowly. Male and female growth rates were not significantly different.

Fourteen adult northwestern pond turtles were radio-tagged and monitored at Carmine Lake. Turtles in Carmine Lake moved less than has been reported for turtles in riverine habitats. Aquatic home ranges were more restricted to discrete areas within Carmine Lake rather than the comparatively large, linear aquatic home ranges observed in northwestern pond turtles that occupy riverine habitats.

Habitat use was determined during the active season using telemetry of eleven adult turtles and habitat characterization of Carmine Lake. Habitat characteristics were measured at points on a grid consisting of 10 m x 10 m squares across the aquatic habitat. Telemetry was used to determine turtle locations and patterns of habitat use by turtles. The adult turtles avoided shallow water and near-shore habitat, a behavior that probably reflects predator avoidance. Data suggested that turtles may select basking sites over refugia, occurring near basking structures with a 20-30° slope and those that faced east and south more than expected, suggesting that structures enabling return to water and good solar exposure were preferred.

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IV

DEDICATION

To the memory of my mother, Carol Ann Barton

✓

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TABLE OF CONTENTS

	PAGE
ACKNOWLEDGMENTS	iii
LIST OF TABLES	viii
LIST OF FIGURES	ix
INTRODUCTION	1
SPECIES ACCOUNT	2
Taxonomy	2
Geographical Distribution	3
Description of the Subspecies Studied	10
Coloration	
Age Variation	
Size Variation	
Sexual Variation	
Ecology	17
Aquatic Habitat	
Upland Habitat	
Thermoregulation	
Diet and Feeding Behavior	
Seasonal Activity	
Movements	
Reproduction	
Age and Growth	
Survivorship	

Threats to Survival	43
Habitat loss	
Overutilization for Commercial, Recreational, or Educational Purposes	
Disease or Predation	
Other Natural or Man-made Factors Affecting its Continued Existence	
SITE DESCRIPTION	56
South Umpqua Drainage	56
Study Area	57
MATERIALS AND METHODS	65
Capture	65
Visual Observation	67
Telemetry	68
Home Range	
Active-season Movement Patterns	
Habitat Characterization	73
Distance to Shore	
Depth of Water	
Type of Nearest Refugium	
Distance to Nearest Refugium	
Type of Nearest Basking Structure	
Distance to Nearest Basking Structure	
Surface Area of Nearest Basking Structure	
Aspect of Nearest Basking Structure	
Slope of Nearest Basking Structure	
Type of Substrate	
Vegetative Cover Type	
Percent Vegetative Cover	
Habitat Utilization	78

RESULTS	80
Sampling Observations	80
Capture Effort	
Capture Rate	
Observations of Captured Turtles	80
Population Estimate	83
Turtle Size and Growth	84
Visual Observations	86
Telemetry	92
Aquatic Home Range	
Overnight Movements	
Movements over the Study Period	
Habitat Utilization	95
Distance to Shore	
Depth of Water	
Type of Nearest Refugium	
Distance to Nearest Refugium	
Type of Nearest Basking Structure	
Distance to Nearest Basking Structure	
Surface Area of Nearest Basking Structure	
Aspect of Nearest Basking Structure	
Slope of Nearest Basking Structure	
Type of Substrate	
Vegetative Cover Type	
Percent Vegetative Cover	
DISCUSSION	112
Sampling Observations	112
Capture Rate and Effort	

Captured Turtles	112
Population Structure	
Population Estimate	113
Turtle Size and Growth	114
Visual Observations	115
Telemetry	117
Aquatic Home Range Movements	
Habitat Characteristics and Utilization	120
Distance to Shore	
Depth of Water	
Type of Nearest Refugium	
Distance to Nearest Refugium	
Type of Nearest Basking Structure	
Distance to Nearest Basking Structure	
Surface Area of Nearest Basking Structure	
Aspect of Nearest Basking Structure	
Slope of Nearest Basking Structure	
Type of Substrate	
Vegetative Cover Type	
Percent Vegetative Cover	
CONCLUSIONS	127
BIBLIOGRAPHY	131
APPENDICES	138

LIST OF TABLES

TABLE		PAGE
I	Minimum Carapace Length at Which Female Western Pond Turtles Have Been Found Gravid (Order of Decreasing Latitude) (Holland, Pers. Comm.)	15
II	Comparison of External Secondary Sexual Characteristics in Male and Female Western Pond Turtles (Adapted from Storer 1930, Seeliger 1945, and Holland 1991)	16
III	Human Population Increases in Oregon, 1980-1990	50
IV	Common Aquatic Vegetation Present in Carmine Lake	61
V	Upland Vegetation Commonly Found at Carmine Lake	62
VI	Habitat Characteristics Evaluated at Carmine Lake	74
VII	Manual Capture Effort at Carmine Lake, 1987-1993	81
VIII	Population Estimate, 1991-1993	83
IX	Average Growth Rates (mm/yr) of Western Pond Turtles at Carmine Lake, 1987-1993	84
X	Numbers of Turtles Visually Observed at Carmine Lake, 1992-1993	86
XI	Turtles Equipped with Transmitters at Carmine Lake, 1992-1993	93
XII	Home Range Areas of Telemetered Turtles at Carmine Lake, 1992	94
XIII	Mean Distances Moved by Telemetered Turtles	95
XIV	Growth Rate Intervals and Observed Life Stages of Western Pond Turtles ..	114

LIST OF FIGURES

FIGURE	PAGE
1. Distribution of the Western Pond Turtle (<i>Clemmys marmorata</i>); Solid Circles Represent Isolated Locations, Probably Introductions (Holland 1994) . .	7
2. Range of the Northwestern Pond Turtle (<i>Clemmys marmorata marmorata</i>) in Oregon, Solid Circles Represent Introduced Animals (Holland 1994) . .	9
3. Male and Female Western Pond Turtles, Carmine Lake, Oregon	18
4. Map of the South Umpqua Drainage	57
5. Map of the Study Area, Carmine Lake, Douglas County, Oregon	59
6. Schematic Diagram of Single-opening Funnel Trap Used to Capture Turtles .	66
7. Transmitter Fixed on the Carapace of a Northwestern Pond Turtle	69
8. Grid System Used for Determining Radio-tracked Turtle Locations and to Characterize Habitat	71
9. Size Frequency of Turtles Captured Within Each Sampling Season, Carmine Lake, 1987-1993	82
10. Turtle Growth Rate at Carmine Lake, 1987-1993	85
11. Average Number of Turtles Observed Basking at 10:00 and 14:00 Observation Intervals	87
12. Average Number of Turtles Observed Basking at Recorded Air Temperatures, Carmine Lake, 1992-1993	89

13.	Average Number of Turtles Observed Basking at Recorded Wind Speeds, Carmine Lake, 1992-1993	90
14.	Average Number of Turtles Observed Basking with Respect to Precipitation, Carmine Lake, 1992-1993	91
15.	Frequency of Turtle Occurrence and Distances from Shore within Carmine Lake	97
16.	Frequency of Turtle Occurrence and Distances and Water Depths at Carmine Lake	98
17.	Frequency of Turtle Occurrence and Type of Nearest Presumed Refugium within Carmine Lake	100
18.	Frequency of Turtle Occurrence and Distance to Nearest Presumed Refugium within Carmine Lake	101
19.	Frequency of Turtle Occurrence and Type of Nearest Presumed Basking Structure within Carmine Lake	102
20.	Frequency of Turtle Occurrence and Distance to Nearest Presumed Basking Structures within Carmine Lake	104
21.	Frequency of Turtle Occurrence and Slope of Nearest Presumed Basking Structure, Carmine Lake	105
22.	Frequency of Turtle Occurrence and Aspect of Nearest Presumed Basking Structure, Carmine Lake	106
23.	Frequency of Turtle Occurrence and Surface Area of Nearest Basking Structure within Carmine Lake	108

24.	Frequency of Turtle Occurrence and Type of Vegetative Cover within Carmine Lake	109
25.	Frequency of Turtle Occurrence and Percentage of Vegetative Cover within Carmine Lake	110

INTRODUCTION

The northwestern pond turtle (*Clemmys marmorata marmorata*) is one of two native turtles found in the Pacific Northwest and the only native turtle known to occur in southwestern Oregon. This study was undertaken to determine basic patterns of aquatic habitat use, patterns of movement, and population structure of northwestern pond turtles at a relatively undisturbed stillwater site. The study is intended to augment the limited information available on the biology of the northwestern pond turtle and, together with other studies, to provide data essential to refine management of this taxon.

Existing data are largely inadequate to determine conclusively the status of the northwestern pond turtle and to manage appropriately existing populations and habitat. The goal of this study was to address the following objectives to provide some of the information needed for management:

- 1) Determine seasonal aquatic habitat use of northwestern pond turtles in a stillwater environment between late spring and early fall.
- 2) Determine active-season movement patterns.
- 3) Determine aspects of population structure.

SPECIES ACCOUNT

TAXONOMY

Baird and Girard (1852) first described the western pond turtle (*Emys marmorata*) from a small specimen (carapace length [CL] $\approx$ 60 mm [= 2.4 in]) at an unspecified locality near Puget Sound. Subsequently, Hallowell (1854) collected and provided a separate description based on one adult (CL $\approx$ 165 mm [= 6.5 in]) from Posa [*sic* (Poso)] Creek, Kern County, California. To this specimen, he gave the name it *Emys nigra*. Strauch (1862) was the first to use the name *Clemmys marmorata*. Van Denburgh (1922) expanded on the species description and provided a synonymy. Seeliger (1945) partitioned the western pond turtle into two subspecies, the northwestern pond turtle (*C. m. marmorata*), and the southwestern pond turtle (*C. m. pallida*). Selected aspects of coloration and the relative size of certain carapacial plates differentiated the subspecies (see Description of the Subspecies Studied, Page 9). Seeliger used the type locality for the species (Puget Sound, Washington; Baird and Girard 1852) as the type locality for the northern subspecies. The type for the southern subspecies was an adult female (CL = 134 mm) collected on lower Coyote Creek, Orange County, California (Seeliger 1945).

A poorly-defined, broad contact zone in the San Joaquin Valley separates the two subspecies. Seeliger (1945) believed that individuals from the contact zone, which she labeled intergrades, were closer to the northern subspecies. She did not assign the

specimens from Lower (Baja) California because they seemed dissimilar to either subspecies.

Controversy continues to exist concerning the subspecies assignments of Seeliger (1945) for populations found in the Columbia Gorge, and for isolated current and historical occurrences in Nevada, Idaho, and eastern Oregon (USDI 1993a; Holland 1992). The controversy has arisen primarily from incongruent variation in the two characteristics used to define the subspecies. The origin of some isolates remains in question because the ease of human transport of western pond turtles may have resulted in establishment of the species at locations where they did not previously exist (Storer 1930, 1937; Evenden 1948) or in the genetic mixing of historically segregated populations. The taxonomy of the western pond turtle is currently being reevaluated (Holland, pers. comm.), but until this evaluation is complete, the subspecific allocations of Seeliger (1945) remain the accepted taxonomy.

GEOGRAPHICAL DISTRIBUTION

Van Denburgh (1922) and Storer (1930) first described the range of the western pond turtle. Van Denburgh (1922) characterized the species' range as "all the fresh waters of the Pacific Slope" from British Columbia to Lower California, although the southernmost locality actually reported was San Diego (California). Storer (1930) described the range more precisely, stating that it extended "from Vancouver Island and the mainland of British Columbia to northern Lower California." He identified the southernmost localities as El Valle de la Trinidad and San Telmo in the San Pedro Mártir

region of Baja California (Mexico). The eastern boundary of the range was generally identified as west of the Cascade-Sierran axis. Despite extensive locality lists, Klamath Lakes, the Link River at Klamath Falls, and "the vicinity of Klamath Falls, Oregon" were the only Oregon localities cited by either Van Denburgh (1922) or Storer (1930).

After examination of museum records and interviews with local authorities, Storer (1937) modified his earlier statements regarding western pond turtle distribution. First, he retracted the statement that western pond turtles occurred on Vancouver Island (British Columbia). Second, most specimens or sightings from western Washington attributed to western pond turtles were subsequently identified as western painted turtles (*Chrysemys picta*) (Storer 1937). Third, Storer reemphasized the statement of Stanley G. Jewett, Jr. that western painted turtles (*Chrysemys picta as belli*) were common along the Columbia River and occurred southward in the Willamette Valley to the vicinity of Cottage Grove (Lane County, Oregon), noting an absence of western pond turtles in the Willamette Valley. Finally, Storer reported occurrence of western pond turtles in southwestern Oregon; based on his collection of a gravid female western pond turtle near Canyonville (Douglas County); he also had secondhand reports of the species' occurrence along the Rogue River. Storer (1937) reached four general conclusions regarding the range of the western pond turtle: 1) it is the only native turtle west of the Sierra Nevada divide in California; 2) it occurs in southwestern Oregon (essentially Klamath, Rogue, and Umpqua Rivers), but not elsewhere in Oregon; 3) Fort Steilacoom is the only locality where the occurrence of the western pond turtle has been verified in Washington; and 4) no verifiable records of the species exist for British Columbia.

Pope (1939) reported a range for the western pond turtle similar to that presented by Storer (1937). However, Pope defined its occurrence north of the Umpqua River as "problematic," believing the distribution of the turtle in the northwestern portion of the range might not be completely understood. Evenden (1948), recounting Gordon (1939) and Graf et al. (1939) in part, specifically discussed the distribution of the western pond turtle in northwestern Oregon and refuted the assertion of Storer (1937) that the species did not occur north of the Umpqua River. Evenden noted that the western pond turtle was rare near Portland, where the western painted turtle was found, but it was "common on the Willamette River and its tributaries at least as far north as Salem; [and] very common in the sluggish streams and ponds of Benton, Lane, and Linn counties."

Evenden (1948) also discussed the uncertain distribution of the western pond turtle in Washington. He concluded that available verifiable records were either the result of importation or the "unlikely" possibility that the species occurred in Pierce and Thurston Counties but had been unnoticed before the collections of Slater (1939). Storer (1930, 1937) had also suggested the high probability for human transport and expressed concern that such activities could affect the range of the species. Notably, Evenden did not discuss the Puget Sound collection upon which Baird and Girard (1852) based the species description. Holland (1993) discussed the historical distribution of the western pond turtle, and concluded that the historic range in Washington consisted of southeastern Puget Sound and the north shore of the Columbia River roughly between White Salmon and Vancouver (Holland 1993). The origin of the western pond turtle specimens collected in western Washington remains unresolved.

Western pond turtle isolates are also reported from western Nevada (La Rivers 1942, Banta 1963), but the presence of the western pond turtle in Nevada was considered an introduction. Banta inferred that western pond turtles were not introduced, based on local knowledge ("longtime residents" of the Carson Valley and his father, a resident of the Truckee Meadows area) and Cooper's (1863) ambiguous recollection of the species identified as *Actinomys* (= *Clemmys*) *marmorata*. Again, the cautions of Storer (1930, 1937) regarding transport apply. Consequently, the origin of the western pond turtle at some isolated localities east of the Sierra-Nevada-Cascade divide remains uncertain.

The various aforementioned ambiguities regarding the geographic relationships of western pond turtles will remain unresolved without systematic analysis, probably at a biochemical level. To date, biochemical analysis has been applied to western pond turtles solely to identify the level of genetic variation across some populations at a few loci (Holland 1994). A biochemical address of various western pond turtle distributional problems and systematics is needed.

Stebbins (1954, 1966) provided generalized range maps for the western pond turtle, based primarily on data obtained from Storer (1930). Bury (1970) also presented a range map similar to that of Stebbins (1966) but with greater resolution, including points showing collection locations and fossil records (Figure 1). Holland (1991) substantially refined the understanding of the distribution of the western pond turtle (Figure 1), emphasizing its occurrence along water courses and other aquatic habitats throughout the range. Holland noted that the species ranges from sea level to a maximum elevation of



Figure 1. Distribution of the western pond turtle (*Clemmys marmorata*); solid circles represent isolated locations, probably introductions (Holland 1994).

ca. 1370 m (4,500 ft) in the southern Sierra Nevada Range, but north of the Klamath River drainage it is seldom found above 1066 m (3,500 ft).

Holland (1992) detailed the distribution of the northwestern pond turtle in Oregon. Surveys were conducted in five drainage basins in Oregon: Interior Southeastern Oregon, Klamath-Lost River, Rogue River, Umpqua River, Columbia River (excluding the Willamette drainage) and Willamette River. Turtles were found in all regions except Interior Southeastern Oregon. Whereas Storer (1930) and Evenden (1948) found few western pond turtles north of Salem, turtles were observed at 38 sites in the Willamette Valley, of which 26 were north of Salem (Holland 1992). The distribution of the northwestern pond turtle in Oregon based on the data Holland presented is mapped in Figure 2.

Stern and Rosenberg (1992) and Stern et al. (1994) amplified current understanding of the distribution of western pond turtles in coastal southwestern Oregon. They surveyed sites with historical or recent turtle observations and sites with potential pond turtle habitat. Northwestern pond turtles were observed at only three of 24 sites surveyed in 1992. In 1993, survey effort was expanded to include trapping and marking and increasing the number of potential sites surveyed. Of 39 sites surveyed in 1993, western pond turtles were confirmed at 14. Confirmed presence was accomplished by direct observation, photographs, or captured animals turned in to Oregon Department of Fish and Wildlife. Stern et al. (1994) concluded that western pond turtles have a fragmented distribution and occur in a variety of aquatic habitat types in coastal southern Oregon.

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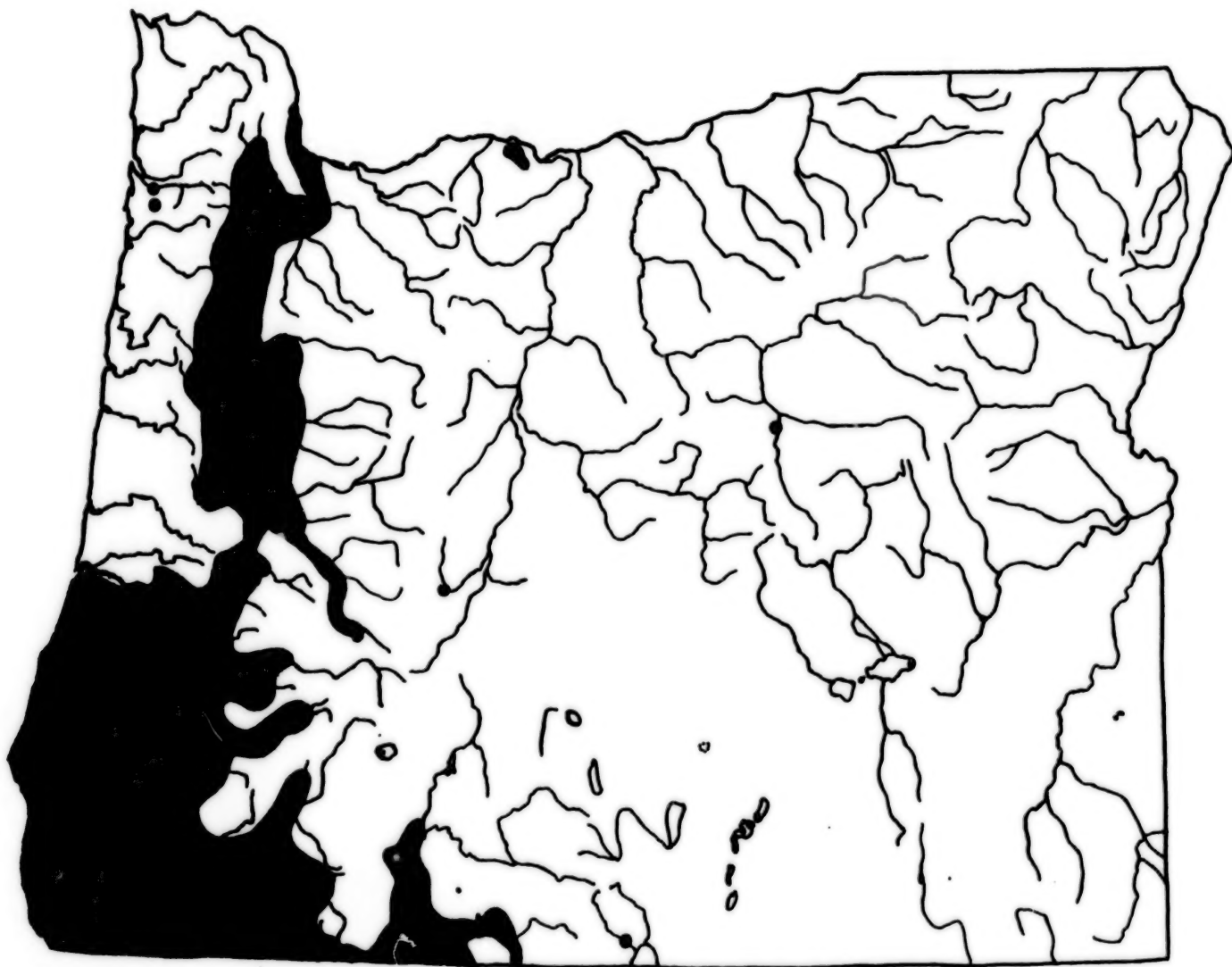


Figure 2. Range of the northwestern pond turtle (*Clemmys marmorata marmorata*) in Oregon; solid circles represent introduced animals (Holland 1994).

DESCRIPTION OF THE SUBSPECIES STUDIED

Seeliger (1945) distinguished the northwestern pond turtle (*C. m. marmorata*) from the southern subspecies (*C. m. pallida*) by (southwestern pond turtle characteristics in parentheses): 1) relatively large inguinal plates (small to nonexistent); and 2) lighter coloration and more obvious reticulations on head and neck (darker with fainter markings).

Coloration

Based on one juvenile (~60 mm) individual, Baird and Girard (1852) described the carapace of the western pond turtle as "yellowish brown marbled with black." Hallowell (1854) expanded on this description based on one 140-mm specimen from California. The upper surface of the animal was described as blackish, with small yellow spots on the upper portions of the head and neck. Hallowell (1854) also noted that the jaw and throat were yellow and the plastron was "yellow in the middle, with large blotches of black or dark brown at the sides, anteriorly, and posteriorly." The underside of tail and extremities was blackish. Whereas previous descriptions of the species were based on single individuals, Van Denburgh (1922) refined the description of the species based on six individuals ranging from 27-164 mm CL. He noted some of the same characteristics earlier authors had described but added that considerable variability in coloration existed. Carapace coloration ranged from olive-colored to black with few to numerous irregular black lines and reticulations. Van Denburgh described the plastron

color as yellow with black or brown blotches or dark lines along the margins. Variability in head and limb coloration was noted, with yellow to brown background color and contrasting light or dark reticulations.

Seeliger (1945) used color as one of two features to differentiate northwestern and southwestern pond turtles. She described the northern subspecies as "... blackish above, the upper part of head and neck presenting numerous very small yellow spots upon a black ground; anterior extremities with a tinge of yellow; under jaw and throat yellow, with dark colored markings." Coloration of the southern subspecies carapace was described as "light brown with darker brown spots and radiating lines", with the underside of the head and neck generally darker than the northern subspecies. Seeliger (1945) also stated that intermediates in coloration occurred in the San Francisco Bay area and the San Joaquin Valley.

Holland (1991) further refined descriptions of coloration for the western pond turtle, stating that reticulations on the carapace were often arranged radially or semi-radially from the growth centers of each shield. He described the plastron as light yellow to cream with varied degrees of darker mottling, usually around the shield margins. He noted that the plastron also tended to become stained reddish-brown with tannin or other agents at some locations.

Holland (1991) also augmented the description of latitudinal and ontogenetic variation in the coloration of western pond turtles. He reported that background carapace color graded clinally from light (yellowish brown to light brown) in the southern

subspecies to dark (dark brown to black) in the northern subspecies. He also noted that older turtles tended to lose melanin in the carapace, exposing the color of the underlying bone; and therefore they displayed a mottled appearance. Holland stated that a dark brown or black spot occurred on the center of the throat in yearling western pond turtles, resembling a similar feature in map turtles (*Graptemys* spp.). In western pond turtles, this feature usually faded by the end of the first year.

Sexual variation in head and neck coloration was also evident (Holland 1991) [see section on Sexual Variation, page 15]. In general, females tended to resemble subadults in head and neck coloration, whereas males generally displayed lighter coloration on the undersides of the head and neck. This sexual variation also varied geographically, northern male turtles were generally darker, and ontogenetically, older male turtles generally had lighter coloration of the neck and throat.

Age Variation

Van Denburgh (1922) commented on several aspects of ontogenetic variation in western pond turtles. Contrasting with the reticulations on relatively uniform background coloration in adults, carapacial plates of "young" turtles (age or size not specified) were brown in the center with a band of light brown around the margin, and longitudinal bands marked the limbs, neck, tail, and gular region. He observed that the shape of the carapace of young turtles (as viewed from above) was more rounded than the more anterioposteriorly elongated carapace of adults, and that young turtles had a median ridge lacking in adult turtles. Van Denburgh also noted that the carapace of adults became

broadly posteriorly. Lastly, he found that in young turtles, the plates of the carapace could be brown centrally and lighter brown or dull yellow peripherally, and the markings on the limbs, tail, neck, and gular region formed irregular longitudinal bands.

Storer (1930) provided descriptive data for 15 non-adult turtles (CL < 95.0 mm). He reported greater variation in the characteristics Van Denburgh (1922) had noted. Specifically, some young turtles were wider anteriorly rather than posteriorly, and some lacked vertebral ridges. Based on the examination of four specimens, Storer (1930) reported three additional characteristics unique to very young western pond turtles (27.8-30.8 mm CL). These characteristics were: 1) granulated, rough-surfaced scutes; 2) smooth areas on the medial margins; and 3) a plastral scar at the point of absorption of the yolk sac.

Seeliger (1945) discussed age variation in western pond turtles based on the examination of 158 specimens between 20 and 180 mm CL. She found that the appearance of the carapacial surface was correlated with the size, and presumably the age, of the individual and could be separated into stages: 1) most individuals <40 mm had granular scutes ($\bar{x}$ = 30.1 mm CL, n = 22); 2) individuals between 40 and 140 mm CL, mostly those <110 mm CL ($\bar{x}$ = 67.9 mm CL, n = 66), had a granular portion and radiating and concentric ridges on each scute; 3) individuals between 80 and 180 mm CL had only concentric ridges on each scute, mostly between 100 and 150 mm CL ($\bar{x}$ = 125.7 mm CL, n = 37); and 4) individuals with comparatively smooth carapace (few or no concentric or radiating ridges) were >100 mm CL, but most with this appearance

were >125 mm CL ($\bar{x}$ = 145.9 mm CL, n = 47). Tail length and width were found to be inversely proportional to CL. In individuals <50 mm CL, the following characteristics were noted (contrasts with adult-sized individuals in parentheses): 1) presence of a median dorsal ridge (present in some); 2) flat, weakly-notched supracaudals (upturned and distinctly notched); 3) laterally flattened carapace (usually with a slight posterior bulge); 4) gray to yellow plastron (uniformly yellow or blotched); 5) carapace primarily brown, some with yellow at the margin (gray to horn [= tan] with varied degrees of brown markings); and 6) primarily dark-colored head and limbs (variable, but not primarily dark-colored; see Sexual Variation, page 15 and Coloration, page 10).

Size Variation

Few authors specifically discuss variation in size in western pond turtles. Pond turtles in Oregon range in maximum adult size from approximately 190 mm in the north to 210 mm in the south portion of the state (Holland, 1994). Holland (1991) states that maximum adult CL decreases with stream size and increasing altitude and latitude, but the significance of that variation is not understood.

Holland (1991) discussed potential clinal variation in the minimum CL required for reproduction. Anecdotal accounts exist regarding the minimum size at which male western pond turtles become reproductive, from which Holland (1991) presumed a minimum CL of 110-120 mm. The minimum CL at which females from Oregon and California have been found reproductive varied. The minimum CL of gravid females was found to generally decrease with latitude (Table I). The age-specific size variation for

TABLE I
MINIMUM CARAPACE LENGTH AT WHICH FEMALE WESTERN
POND TURTLES HAVE BEEN FOUND GRAVID
(ORDER OF DECREASING LATITUDE)
(HOLLAND, PERS. COMM.)

Location	n	Minimum CL	Maximum CL	Mean adult CL
Baja California north to Santa Clara Basin	43	119.4	173.8	136.5
Santa Ynez Basin to San Francisco Bay	81	111.9	172.4	145.8
Pajaro-Salinas Drainage	12	114.7	159.4	137.0
Central Valley Interior	60	123.3	180.2	145.3
San Francisco Bay north to Klamath Basin	56	126.6	180.9	152.0
Oregon (excluding Klamath drainage)	14	138.2	177.4	161.5

these data are unknown. Moreover, the data are susceptible to certain confounds (between-year variation and stochastic variation being two) that remain to be addressed before clinal or other variation can be demonstrated with confidence.

Holland (1991) also suggested that reproductive size (in females) may decrease with increasing elevation, but the data upon which this suggestion is based are vulnerable to confounds similar to those mentioned above.

Holland (1991) stated that turtles from small creeks and streams were generally smaller and females were found to be reproductive at a smaller size than those found in larger water courses. He also stated that it is not known whether the smaller body size is correlated with a younger age or slower growth rate.

Sexual Variation

Storer (1930) first described secondary sexual characteristics visible in western pond turtles, based on differences in the plastron, carapace, and tail (Table II). Seeliger

TABLE II.
COMPARISON OF EXTERNAL SECONDARY SEXUAL CHARACTERISTICS
TYPICAL OF MALE AND FEMALE WESTERN POND TURTLES
(ADAPTED FROM STORER 1930, SEELIGER 1945,
HOLLAND 1991).

Characteristic	Male	Female
Shape of the plastron	Concave	Flat or slightly convex
Cloacal opening	At or beyond the rear edge of the carapace	At or anterior to the rear edge of the carapace
Tail (no significant difference in length or width)	Enlarged base, sometimes difficult to distinguish from female	Base not obviously enlarged, gradually tapered
Carapace	Lower relative height (less domed)	Higher relative height (more domed)
Coloration	Yellowish to white chin and throat with few dark markings, particularly in the northern subspecies	Darker chin and throat with more numerous and darker markings
	Upper jaw (maxilla) light-colored with few markings	Upper jaw (maxilla) with numerous markings or striations
Rostrum	Angle between top of head and front of nose acute, usually 10-15 degrees from vertical	Angle between top of head and front of nose usually right-angled
	Nose relatively long	Nose relatively short

(1945) expanded the discussion of the same characteristics, but added sexual dimorphism in coloration. Seeliger gathered her data by examining of several features of up to 63 male specimens over 110 mm CL and 63 female specimens over 100 mm CL. Seeliger noted that some characteristics varied individually (carapace shape), and in some instances, geographically (carapacial markings). Holland (1991) added morphological differences in the rostrum to previously described sexually dimorphic characters. External sexual variation as seen in individuals from Carmine Lake, Oregon, are illustrated in Figure 3.

ECOLOGY

Aquatic Habitat

Early reports of the patterns of aquatic habitat use were very generalized. Van Denburgh (1922) stated that the western pond turtle was "...almost exclusively aquatic, preferring ponds and small lakes to running water, but is sometimes encountered in rivers or creeks. . ." This statement, however, may reflect a bias due to Van Denburgh's focus on surveying stillwater habitats. He also stated that the species used water for refuge and rocks, logs, and calm water for basking. In stream habitats, Storer (1930) observed turtles using deeper pools on summer days and traversing riffles in the early morning and evening. In Sutter County (California), overwintering underwater in mud was observed in a few instances during November, December, and January (Storer 1930).

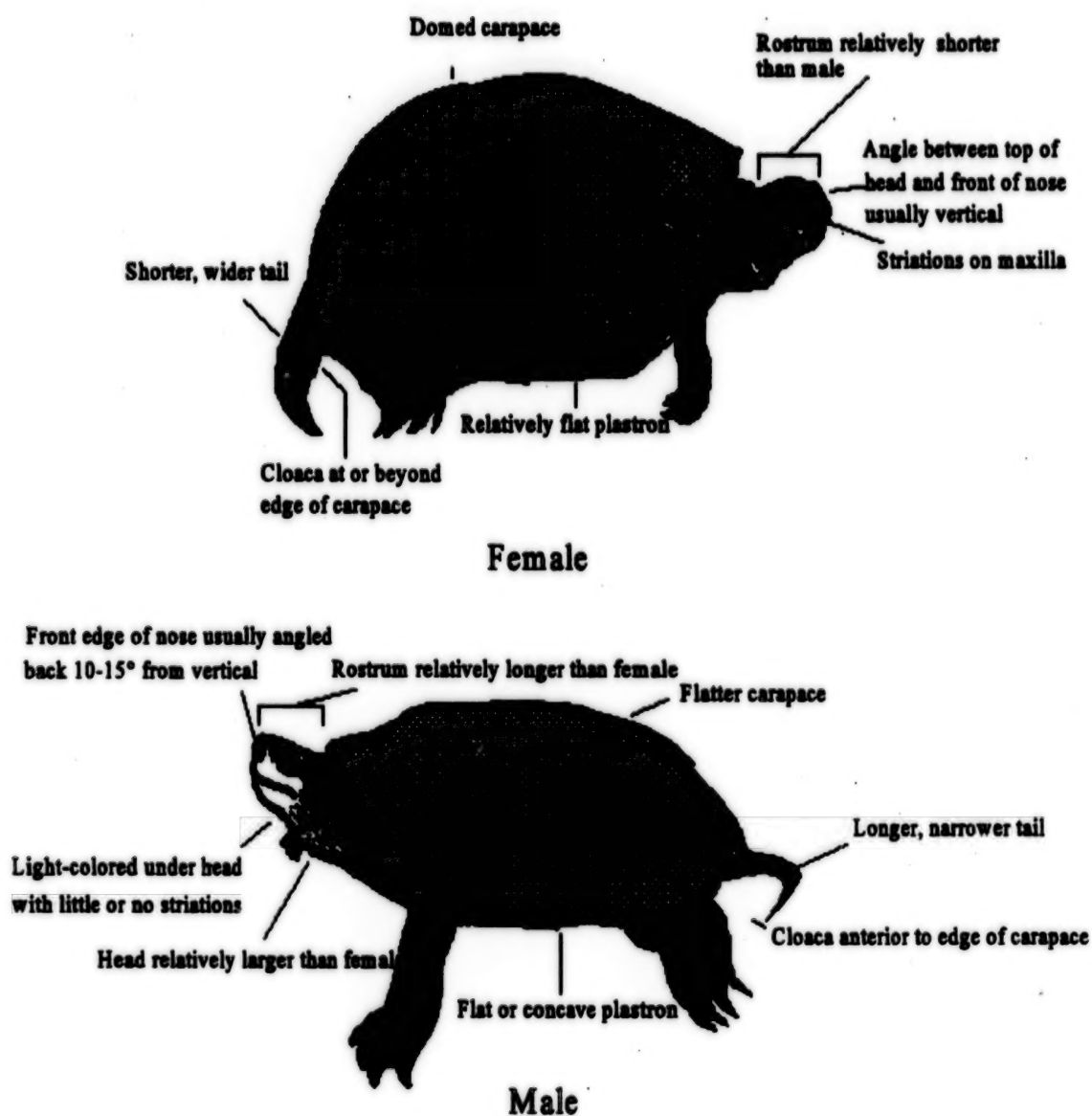


Figure 3. Male and female western pond turtles, Carmine Lake, Oregon.

Most basic aspects of habitat utilization patterns described here have simply been repeated in general accounts of the species (Pope 1939, Stebbins 1966, Nussbaum et al. 1983). However, each account has attempted either to better define or expand on the habitat niche description for the species. In particular, Pope (1939) noted that although ponds and streams are preferred habitats, western pond turtles also use rivers, lakes, marshes, sloughs, and reservoirs. Stebbins (1966) also reported that the species has sometimes been observed in brackish or sea water. Holland (1991) commented on the use of artificial habitats such as sewage ponds, reservoirs, irrigation ditches and canals, excavated farm ponds, and mill ponds. However, he emphasized that these habitat types rarely appear to contain sustainable populations. Holland also recognized that juvenile (<120 mm) turtles required a distinctive aquatic "microhabitat": shallow water (generally < 30 cm deep) and low emergent or floating aquatic vegetation.

Evenden (1948) reported that in Oregon, the northwestern pond turtle occurred in tributaries, sloughs, ponds and river-bottom lakes in the Willamette Valley (the northern limit of abundance), and in "...rapid-flowing, clear, cold, rock and gravel 'trout streams' of the Cascade foothills". He did not address the relative abundance of northwestern pond turtles among habitat types. Evenden also corrected Storer's (1930) earlier statement that the western pond turtle occurs within the Transition Life Zone (Merriam 1898) in the northern part of its range. Evenden wrote that the species occurs from the Arid Transition Zone (foothills of Cascades in the Willamette Valley) to the Upper Sonoran Zone (dry climates of the lower Rogue Drainage and parts of the Willamette Valley).

Few authors have attempted to elucidate habitat utilization patterns for the western pond turtle beyond the information provided in general accounts, and such quantitative data on the northwestern pond turtle in Oregon are lacking. Based on data collected from Hayfork Creek (California), Bury (1972a) determined that a significant positive correlation existed between number of turtles and large pools (based on length) with deep water and an abundance of cover. He also described the use of aquatic habitat for thermoregulatory behaviors [see Thermoregulation]. Holland (1991) emphasized that western pond turtles use of a variety of in-water structures (rocks, logs, holes, undercut banks, mud, vegetation, beaver lodges) as refugia. He stated that refugia may be critical for maintaining populations in some habitats (e.g., small streams).

Differences in habitat selection by juveniles and adults have been noted (Holland 1991, Reese 1996). Juveniles tend to occur in shallow (< 30 cm), stillwater habitats with extensive emergent vegetation or other structures such as willow branches (Holland 1991). Reese evaluated juvenile selection of water flow, canopy cover, water depth, and water temperature at two areas in the Trinity Basin, California. Reese found that, in one area of her study, juveniles characteristically used warm water, but found no pattern of use at most sites.

Rathbun et al. (1993) used telemetry to observe the movements of turtles in Pico and San Simeon Creeks (San Luis Obispo County, California). Turtles were found to move between aquatic and upland habitats at different times (see also Upland Habitat section, below). Turtles tracked in a local pond, Pico Pond, generally remained there

during the winter. Those residing in creeks (e.g., San Simeon Creek) were apt to leave the water course during the winter and occasionally at other times during the year. Based on their persistence in ponds during winter months, turtles remained in aquatic habitats when water temperatures were low. Rathbun et al. (1993) concluded that turtles emigrated from water courses during periods of adverse water conditions (e.g., excessive salinity) other than low water temperature.

Upland Habitat

Early accounts seldom discussed the occurrence of the western pond turtle in upland habitats. When collected in upland habitats, the individuals were usually females presumed to be in the process of nesting. Van Denburgh (1922) found turtles "on land while crossing from one body of water to another." Turtles crossing roads were "probably. . . looking for suitable places to lay eggs." Storer (1930) thought that only females conducted "excursions" on land for oviposition. Based on 12 records of females found in uplands, he hypothesized two distinct nesting habitat types: 1) sandy banks near large rivers, and 2) steep hillsides in foothill regions. Until recently, little effort was devoted to identifying the pattern of western pond turtle use of upland habitats. Recent data have revealed a greater and more varied use of upland habitat than was previously believed. Unfamiliarity with terrestrial habitat use for purposes other than nesting and the relative ease of observing turtles in aquatic habitats encouraged a bias for early observations of turtles in aquatic habitats.

The failure of western pond turtle eggs to develop normally under hydrated conditions (Feldman 1982) suggested that typical nesting conditions were probably more xeric than those that characterize other aquatic turtles. Western pond turtles have thin, but hard-shelled, brittle eggs (Holland 1991, 1994). Congdon and Gibbons (1990) state that soil moisture of freshwater turtle nests is associated with egg calcification; the more calcified the shell, the less the eggs are dependent on moist soil conditions. In contrast, freshwater turtles (e.g., red-eared sliders (*Trachemys scripta*) and common snapping turtles (*Chelydra serpentina*), both with flexible eggshells, are more reliant on hydric soils. Mud turtles (*Kinosternon* spp.), like western pond turtles, have hard-shelled eggs which are resistant to water loss (Packard et al. 1982) and do not require moist soils for nesting (Burke et al. 1994).

Holland (1990, 1994) collected substantial evidence that supported the belief that xeric conditions are required for western pond turtle nesting habitat. Based on the data for >250 nest sites, Holland (1994) concluded that female western pond turtles require dry, open, grassy sites with well-drained, clay-rich soils for nesting. Open, grassy sites that are exposed to the sun are necessary to provide adequate incubation temperatures. Clay-rich soils may allow the excavated nest to maintain its structural integrity, provide a favorable thermal environment, or both. None of these factors have been experimentally addressed for western pond turtles.

More recent data have shown that upland habitats are also used for overland movements, overwintering, and other periods of inactivity. Rathbun et al. (1993)

documented seasonal use of upland habitats. Pond turtles that used upland habitats during "dormant" periods reportedly traveled relatively long distances and spent many days out of water. Western pond turtles have been found to make significant overland movements (Holland 1991, 1992, 1994) that may vary geographically (Holland, pers. comm.). Thick vegetative cover characterized upland sites used during periods of inactivity in Central California, and inactive turtles were usually concealed under leaf litter (Rathbun et al. 1993). The most extensive use of upland habitats occurred in winter. Although winter use of upland habitats was not linked to changes in water temperature, it may be linked to other specific or coordinated environmental changes (Reese 1996).

Thermoregulation

As in all reptiles, thermoregulation is an important aspect of turtle biology. Basking, the primary method of thermoregulation in aquatic turtles, is defined as "sustained, deliberate exposure to heating by external sources" (Bury 1972a). Moll and Legler (1971) also examined thermoregulatory behavior in the red-eared slider. They found that thermoregulation could be classified in two behavioral categories: 1) emergent (= atmospheric or aerial) basking, lying sedentary on substrates out of water, and 2) water (= aquatic) basking, lying sedentary at the surface of the water. Surfaces used for emergent basking include logs, rocks, banks, vegetation, stumps, and other debris. Both emergent and water basking have been observed in most freshwater turtles (Cagle 1950, Boyer 1965, Bury 1972a, Spotila et al. 1990, Holland 1991). Light intensity has been found to be the most important factor affecting basking and heat gain (Boyer 1965).

Turtles were shown to exhibit a preference for unshaded basking sites, and cloacal temperatures decline rapidly relative to decreases in light intensity (i.e., increased cloudiness).

Water temperature has been shown most important in determining the initial body temperature of basking turtles (Boyer 1965). Emergence alone has been shown to cause heat gain, largely because air temperature is almost always higher than the water temperature over inland water bodies during the season when turtles are active. Subsequent insolation during basking has been demonstrated to cause an increase in body temperature over time, regardless of air temperature. For these reasons, light intensity was determined to be the most important physical factor affecting basking in turtles.

Western pond turtles are frequently observed while emergent basking. Bury (1972a) noted that emergent basking behavior in northwestern pond turtles was most common when the associated body of water was in direct sunlight. Bury found that western pond turtles regulated body temperatures between 24° and 32°C during summer months. He stated that the emergent basking generally peaked between 09:00 and 10:00 at the elevation (630 m [2300 ft.]) and latitude (~40.5°N) of the Hayfork Creek study site. Holland (1991) found that western pond turtles were observed emergent basking at air temperatures between 10° and 38°C.

Basking duration may be affected by several factors. Bury (1972a) examined the effects of time of day, disturbance, and season on basking duration. Atmospheric basking duration was found to decrease about one hour from morning (08:00) to afternoon

(12:00). Basking averaged 6.2 min longer when emergent basking was voluntarily terminated ($n = 221$) rather than when the turtle apparently terminated basking because of some disturbance ($n = 146$). Bury also compared emergent basking in July and September. He found no statistical difference in the duration of basking, although he observed considerably more turtles/day basking in July ($\bar{x} = 54.8$; $n = 219$) than September ($\bar{x} = 14.3$, $n = 43$). Whether differences observed were related to differences in population composition in July versus September were not addressed. Generally, the duration of basking is shorter when initiated later in the day, interrupted by disturbance, and/or initiated later in the active season.

Western pond turtle basking behavior may substantially affect thermoregulation. Pond turtles often selected basking sites with ample solar exposure, such as rocks or banks that slope toward the sun (Bury 1972a). Bury (1972a) found no preference for orientation in a particular direction, but pond turtles may preferentially orient the posterior portion of the body toward the sun (Holland 1991). Bury observed that upon emergence onto a basking site, turtles extended their necks and limbs with the head and neck held high. After the carapace dried, the head and neck were gradually withdrawn until completely retracted, usually within 20-30 minutes. Retraction was occasionally interrupted by a position change on the basking site. Pond turtles often interrupted emergent basking to enter or dip parts of their body in water, presumably to reduce body temperature (Bury 1972a; Holland 1985a). The behavior may also prepare turtles for diving or alert them of potential predators in the water (Bury 1972a). Bury (1972a) also

observed that as turtles basked longer out of water, a larger proportion of the exposed body was shaded. Turtles seen using these behavioral cooling mechanisms basked for longer intervals than turtles that did not employ them (Bury 1972a).

Bury listed several habitat components which appeared to have an effect on emergent basking, including: 1) the amount of basking allowed by a combination of the local topography, the pattern of vegetation shading, and shape of the water body; 2) the nature of the basking site substrate; and 3) the location and slopes of basking sites. Besides these habitat components, the amount of time turtles engaged in emergent basking may differ significantly with latitude because of the greater thermal input required to heat the surface water daily at higher latitudes (Holland 1991).

Water basking occurs in many aquatic turtle species (Cagle 1950; Boyer 1965; Bury 1972a; Spotila et al. 1990; Holland 1991) and may take place in any relatively stillwater habitat, including deep stream pools. Although the benefits of water basking have been discounted (Boyer 1965), water basking has been well-established as an "opportunistic strategy of thermoregulation", used especially during intervals of warm air temperatures ($>27^{\circ}\text{C}$) (Bury 1972a).

Western pond turtles commonly water bask (Bury 1972a, Holland 1991). Bury has provided the most substantial data and observations on water basking through his study of northwestern pond turtles at Hayfork Creek. He found that aquatic basking involved not only insolation at the water surface but also apparent selection of putatively optimal water temperatures, particularly when air temperatures were unfavorable.

Aquatic basking occurred when available water temperatures were higher than air temperatures. Turtles also used water to retreat from cool air as well as from air temperatures that were too warm ($>32^{\circ}\text{C}$). Movements to shade were also employed to reduce unfavorably high temperatures. Bury suggested that water basking may be as important to thermoregulation in freshwater turtles as emergent basking.

Some basking behavior was determined to result in benefits other than thermoregulation. Boyer (1965) observed turtles selecting basking sites with one or more of the following characteristics: higher elevation, appropriate site size relative to body size (seldom emerging on sites less than two-thirds their body width), greater distance from shore, and visible horizon. These characteristics were presumably chosen to avoid predators. In addition, it was noted that basking allowed drying of the integument. Captive sliders developed infections when kept in tanks with no basking sites. Boyer (1965) concluded that some aspects of basking behavior had no apparent effect on heat gain and thermoregulation and accomplished other life needs, such as skin conditioning.

Diet and Feeding Behavior

Most early accounts of diet or feeding behavior in western pond turtles were limited to field observations, anecdotal information, or examination of the stomach contents of few individuals. Early accounts mentioned the diet of western pond turtles (Van Denburgh 1922, Storer 1930, Evenden 1948). Stiehl (1970) observed diurnal and nocturnal feeding in western pond turtles. Several more recent studies have augmented

current understanding of western pond turtle diet and feeding behavior (Bury 1986; Holland 1985a, 1985b, 1991).

Pond turtles are reported to eat a wide variety of foods. Van Denburgh (1922) found "a locally common species of aquatic beetle [species unspecified]" filled the stomach of one female encountered during oviposition "along the West Fork of the Gabriel River" (Los Angeles County, California). Storer (1930) noted that western pond turtles were attracted to traps baited with meat or fish, and in a general account Pope (1939) stated that they are attracted to earthworms (Family Lumbricidae), dead minnows (Family Cyprinidae), grasshoppers (Order Orthoptera), or liver. Pope also remarked that turtles were observed feeding on neuropteran (dobsonfly, alderfly) larvae and aquatic beetles. Evenden (1948) observed northwestern pond turtles in a lake near Corvallis, Benton County, Oregon, feeding "...extensively on the 'pods' of the yellow pond lily (*Nuphar polysepalum*) during the summer and fall." Evenden (1948) also noted that unspecified numbers of pond turtles had been observed feeding on a dead mallard duck (*Anas platyrhynchos*). Bury (1986) dissected the stomachs of 119 western pond turtles, and examined their contents. Food items found in 77 individuals included invertebrates, fishes, larval and adult frogs and frog parts, and a rodent toe. Bury found that food was primarily aquatic invertebrates, though some food organisms were terrestrial or volant. He also concluded that western pond turtles prefer live or dead animal tissue because plant material was consumed in proportions much less than its availability. Although based on volume, the bulk of the diet was invertebrates, some individuals (especially

males) took vertebrate material in large quantities. Holland (1985a) also flushed the stomach contents of over 500 western pond turtles and found invertebrates almost exclusively. Only two vertebrate items were located, both thought to have been scavenged.

Holland (1991) discussed geographic variation in the prey of western pond turtles. In Central California, odonates (dragonflies and damselflies), chironomids (midges), aquatic coleopterans (beetles), mysidaceans (opossum shrimps), and amphipods (scud) comprise most of the diet. Vertebrates comprised only a minor portion of the diet (two small fish in >500 stomach flushings). In addition to invertebrates found in Central Californian turtles, the diets of northwestern pond turtles in Northern California consisted primarily of trichopteran (caddisfly) and ephemeropteran (mayfly) larvae, whereas vertebrates (speckled dace (*Rhinichthys osculus*) [a fish], foothill yellow-legged frog (*Rana boylei*) larvae and metamorphs, and possibly California tiger salamander (*Ambystoma californiense*)) appeared to make up a minor portion of the diet. Fragmented vertebrate prey may represent mainly carrion. Crayfish and larval caddisflies were important components of the diets of pond turtles examined in Oregon as well as of turtles from more southerly localities. Holland (1994) suggested that carrion may be a locally and/or seasonally important part of the pond turtle diet, noting recurrent observations of scavenging. As Holland (1985a, 1991, 1994) emphasized, western pond turtles are dietary generalists, with diet varying with location and season, depending on what is available.

Daily feeding patterns have been observed by Stiehl (1970) and Holland (1985a; 1991). Holland (1985a; 1991) stated that most foraging occurs during two periods, early morning and late afternoon into evening. Stiehl (1970) observed diurnal and nocturnal feeding behavior in a pond in Jackson County, Oregon. Diurnal feeding was initiated shortly after sunrise and peaked around 09:00. Swimming movements similar to those observed in the morning were also observed in the afternoon but were found to be associated with aquatic basking (see Thermoregulation). Nocturnal behavior was observed by attaching a 5 mm x 2 mm battery-powered light to the carapace of 15 individuals. The 1127 m² study area was also lit in a grid pattern in 7 m x 7 m intervals with floating battery-powered red lamps. Nocturnal observations indicated that the equipped turtles fed within an identified "home area" then buried themselves in the mud at the bottom of the pond. The turtles remained buried until shortly after sunrise when they began feeding again. Differences were noted in the habitat chosen for nocturnal versus diurnal feeding. Diurnal feeding occurred in heavily vegetated areas, whereas nocturnal feeding occurred outside these areas.

Pond turtles have been observed feeding by at least four methods: 1) capturing prey in the water column (Holland 1991); 2) floating at the surface of the water, then lunging and biting at prey (Bury 1986, Holland 1991); 3) taking prey terrestrially and returning to water to consume it (Bury 1986; Holland 1991); and 4) opening the mouth, sucking in water and prey, and expelling water through the nose (= gape-and-suck feeding or neustophagia) (Holland 1985a; Bury 1986). Western pond turtles probably

must be submerged to swallow prey (Stebbins 1966; Holland 1985a, 1991; Bury 1986). The need for submersion is thought to facilitate swallowing, but mechanical details that require this behavior are unstudied.

Bury (1986) provided detailed information on the feeding ecology of the western pond turtle based on observation of turtles at Hayfork Creek, California. The turtles studied exhibited sex and age variation in their diets. Females ate a larger variety, but fewer food types than did males. Males were also found to ingest larger food items than females, but females more frequently ingested a significantly greater volume of filamentous algae. Males also ate larger numbers and volumes of dipteran larvae and vertebrates (foothill yellow-legged frog adults and tadpoles, Pacific lamprey (*Lampraea tridentata*), and Klamath smallscale suckers (*Catostomus rimiculus*)). Bury speculated that the difference may be related to several factors: 1) the relatively larger head to body ratio in males; 2) intraspecific competition; and 3) greater nutritional needs of reproductive females. Females may have eaten more plant material because of key nutrients provided by plants for turtle reproduction. The specific nutrients provided were not discussed, but plants were the most abundant food source. The benefit of obtaining the most abundant food source for less effort may have outweighed the cost of digesting plant material, especially for gravid females.

Based on the Hayfork Creek data, juvenile western pond turtles were significantly more carnivorous and consumed smaller prey than adults (Bury 1986). Whether these differences can be generalized to other northwestern pond turtle populations or to

different years is not known, but data from other studies of turtle species suggested similar dietary shifts (Moll 1976; Parmenter and Avery 1990). Bury suggested that one reason juveniles are more carnivorous is because the higher energy yield of such prey may satisfy the relatively higher metabolic requirements of developing juveniles. Bury also suggested that plant material may have been accidentally ingested while preying on animals in algal mats. Adults have larger mouths, so they may incidentally ingest greater amounts of plant material. Parmenter and Avery (1990) provided several hypotheses regarding a parallel dietary shift observed in red-eared sliders (*Trachemys scripta*):

1) juveniles fulfill greater demand for amino acids by consuming animal prey; 2) compared to adults, small turtles use less energy and derive more energy pursuing and consuming live animal prey since relative to body size, the prey is larger and provides greater energy; and 3) differences in microhabitat selection provide greater animal prey availability to juveniles.

In summary, western pond turtles eat primarily invertebrates, as well as many other items in lesser amounts, including plant material and carrion. They display geographic and seasonal variation in a diet dominated by invertebrates. Selectivity and preferences in diet have not been examined. Pond turtles also display variation in diet associated with age and sex, with adults and females showing slightly more herbivory than juveniles and males, respectively.

Seasonal Activity

Western pond turtles generally have three types of seasonal activity: 1) nesting, 2) non-nesting use of terrestrial habitats during periods of adverse aquatic conditions, and 3) aquatic habitat use. The period and extent of seasonal use of habitats depends on latitude, altitude, and environmental conditions. Nesting generally occurs in late spring through summer. Storer (1930) provided data on oviposition for six captive females. These turtles laid eggs between June 21 and July 2. Four laid eggs in the morning, and the other two laid eggs at night. Storer (1937) also reported the collection of a gravid female turtle near Canyonville, Douglas County, Oregon, on 2 July 1933. Graf et al. (1939) commented that oviposition had been observed in June near Peoria, Linn County, Oregon. Evenden (1948) stated that females were in terrestrial habitats, preparing to nest, in late April and early May in the Willamette Valley. Rathbun et al. (1993) observed six individuals make nesting attempts at 13 sites in San Simeon and Pico Creeks, San Luis Obispo County, California. They stated that May-June was the most important time for nesting. Nesting was found to occur primarily in the afternoon. Three of the females were observed to lay two separate egg clutches during the one-season study period. The nesting females were also found to be intolerant of human disturbance, often abandoning attempts to nest when they encountered unusual disturbance.

Northwestern pond turtles, like most temperate turtles, have periods of inactivity during the winter months. Early accounts focusing on aquatic habitat use may have led to speculation that turtles "hibernated" at the bottom of ponds and streams (Storer 1930;

Pope 1939; Stebbins 1966). Storer (1930) indicated that turtles of temperate areas "hibernate" and that the seasonal characteristic varies with latitude and altitude. Storer (1930) described a commercial trapper's method of creating an artificial over-wintering area by burying turtles in approximately 3 inches (7.6 cm) of mud and 8 inches (20.3 cm) of leaves at the onset of cold weather. The turtles created a hole in the mud through which they could breathe. Evenden (1948) stated that turtles in the Willamette Valley were inactive between November and February.

Recent evidence shows that, in addition to overwintering, western pond turtles use upland habitat to avoid adverse aquatic conditions. Although western pond turtles occur in rivers with high flows, they are often absent from these rivers during periods of highest flow when they conceal themselves in upland areas up to 0.5 km from the water course (Rathbun et al. 1993; Reese, 1996; Goodman 1997). Rathbun et al. (1993) found that turtles also avoided periods of high summer salinity in a coastal lagoon. Reese (1996) also wrote that turtles left ponds and concealed themselves in upland habitats or traveled to other ponds when water temperatures got very warm or ponds dried.

Movements

Four types of movements have been observed in western pond turtles: 1) daily short-term movements, 2) long-term dispersal; 3) movements associated with nesting, and 4) movements associated with terrestrial inactivity.

Bury (1970) examined the daily movement patterns of western pond turtles in Hayfork Creek. He estimated distances moved primarily from the point of release after

capture to the next point of recapture. Limited telemetry work was also conducted over a period of approximately four days (until equipment failed). Telemetry studies involved three adult males, of which only one was tracked long enough to obtain substantial data. This turtle moved an average of 175 m/day (range = 50-300 m/day). Bury (1970) suggested that the general decline in movement over time reflected an initial response to handling during capture and placement of the transmitter.

Bury (1970) presented data on short and long-term movements determined from recapture locations. Periods between individual recaptures varied from 0-94 days. Distances moved between recaptures varied widely and were not correlated with length of time between captures. However, males seemed to move greater distances than females or juveniles within a season as well as between seasons. On average, males moved 2.1 and 2.5 times further than females and juveniles, respectively, during one season. Bury also evaluated the distances moved over spans of one to three years. Males moved an average of 1.1-2.6 times further than females or juveniles during the one and two-year intervals. All movement Bury observed was apparently within Hayfork Creek; no terrestrial movement was noted.

Seasonal movements to and from waterbodies were noted in studies in West Eugene, Lane County, Oregon (Galen 1994; CH2M Hill 1994). Pond turtles frequently followed waterways (e.g., channels and ditches) in the West Eugene area, and seldom made overland movements (Galen 1994). Holland (pers. comm.) has also observed the movements of some individuals during mark and recapture studies. Individuals captured

and marked in one pond or stream have been recaptured in the same season up to 4 km (2.5 mi) from their initial capture site. The cause of these movements was not determined.

Numerous anecdotal accounts are available describing the terrestrial movements of gravid females. Van Denburgh (1922) noted several turtles seen crossing a road at Lower Klamath Lake on 12 June 1918, and presumed that they were females in search of suitable oviposition sites. Storer (1937) stated that females may climb hills and travel considerable distances in an attempt to locate suitable nesting habitat. He reported that hatchling turtles were found about 0.4 km in distance (0.25 mi) and 90 m (300 ft) in altitude above a lake where adults were found and presumed the hatchling turtles had emerged from nearby nests. Gordon (1939) stated that western pond turtles in Oregon deposited eggs in fields or banks close to water.

Rathbun et al. (1993) used telemetry to track 10 gravid females in San Simeon and Pico Creeks, San Luis Obispo County, California, and record their movements and nesting behavior. Four nests were located during the study. Three transmitter-equipped females were observed conducting 2-to-4-day terrestrial excursions associated with oviposition. Excursions involved movements at least 30 m landward of water and included periods of inactivity at 2-3 terrestrial locations for intervals of approximately four hours.

Reese (1996) systematically searched for nest sites within 400 m of Lewiston Reservoir, Trinity County, in northwestern California. She found evidence of a former

nest site (indicated by egg shell fragments) approximately 2 m from the nearest water body. Although six other potential nesting areas were identified, no other evidence of nests was found.

Goodman (1997) located 31 southwestern pond turtle nests at two locations in southern California. Sixteen nests were found at nine nest sites in Chino Hills State Park, Riverside County, and 15 nests were found at eight sites on the West Fork San Gabriel River, Los Angeles County. The nine Chino Hills sites averaged 16.2 m (range 1.5-48.2 m) from water and 6.1 m (range 1.5-12.4 m) above water. The eight sites at the West Fork San Gabriel River averaged 28.7 m (range 18.3-47.3 m) from water and 13.6 m (range 3.35-32.0 m) above water.

Rathbun et al. (1993) examined terrestrial movements during winter and at other times of the year. Turtles were generally observed in terrestrial locations during adverse aquatic conditions (e.g., high or low temperatures, high water flows, high salinity, low oxygen). They concluded that suitable terrestrial habitat was necessary for western pond turtle survival in San Simeon State Park, San Luis Obispo County, California, during periods of adverse aquatic conditions.

Reese (1996) observed western pond turtles use of upland habitats year-round. The most prolonged periods of terrestriality were associated with overwintering on the mainstem (Trinity County) and south fork (Humboldt County) of the Trinity River, and in a series of agriculture ponds northeast of Santa Rosa, Sonoma County, California (Reese 1996). Reese found 23 turtles using upland habitats for overwintering during one or more

seasons, 1992-1994. Turtles from the riverine sites on the Trinity River used terrestrial habitat for overwintering, whereas some of the turtle in ponds at Santa Rosa remained in aquatic habitat while others overwintered on land. Evidence suggests that turtles are more likely to use terrestrial sites for overwintering to avoid high-flow riverine conditions (Reese 1996, Goodman 1997, Rathbun et al. 1993, Holland 1991).

Overwintering strategies varied between turtles, but an overall strategy (aquatic or terrestrial), general location of overwintering site, and timing of overwintering seemed consistent for each individual. These individual consistencies were thought to reflect reaction to habitat and recurrent conditions within its geographic location and home range such as day length or water flow. Overwintering duration was variable among individuals, but females generally initiated movements earlier and remained at overwintering sites longer than males.

Reese (1996) also determined that turtles at upland overwintering sites used conifer, hardwood or mixed conifer/hardwood forest types. Overwintering sites on the Trinity River averaged 162.5 m ($n = 40$, range 43.7-422.8) from water and 42 m ($n = 39$, range 0-115 m) above the river surface. Other overland movements were observed that were unassociated with overwintering or nesting: dormancy associated with estivation, possible terrestrial basking, and dispersal between water bodies (often using nearby ponds during periods of adverse riverine conditions such as high and/or cold water flows or salt intrusion).

Reproduction

Knowledge of reproductive ecology of western pond turtles is growing, with several ongoing studies and most data unpublished. Data on reproductive behavior are limited primarily to nesting females and oviposition, probably due to the increased likelihood of encountering females on land during nesting attempts. Holland (1988) observed what he presumed to be courtship behavior in the field. The interaction occurred in water. The male pursued the female and was observed repeatedly to "scratch and fan his forelimbs at the carapace of the female." The only female response observed was partial retraction of the head and front limbs and slight elevation (2-3 cm) of the posterior portion of the body by extension of the hind limbs from the aquatic substrate. The interaction ceased when the male apparently saw the observer. Holland (1988) also reported that copulation was observed between mid-June and early September among captive individuals in Southern California.

Rathbun et al. (1993) used telemetry to attempt to determine the nest locations of 10 gravid females. Four nests were located, and two patterns were observed. In one, exhibited by three females, 2-4 day terrestrial excursions were recorded with 4-hour rests at 2-3 sites within 30 m of water, but nest locations were not found. In the second pattern, displayed by four females, eight 4-hour excursions were noted within 35 m of water, and three nests were located. Two of the four females made multiple nesting attempts. Three of the 10 females laid two clutches of eggs, two of these ovipositing in two different nests.

During the study Rathbun et al. (1993) conducted, four excavations with turtle eggs were located. Nests had the following characteristics: good solar exposure; sparse vegetative cover; well-compacted soils of variable composition; average slope of 12.9° ($s = 13.3$, range = $0-30^\circ$); and an average of 4.8 m above creek water ($s = 4.2$ m, range = 1.0-15.0 m). Two nests were probably destroyed by predators, one nest apparently hatched six unobserved young approximately 138 days after oviposition, and one nest was opened and one live hatchling observed. Site fidelity was not apparent in the females observed. However, females tended to nest within 100 m of where they were observed making excursions.

Studies involving the nesting habits of western pond turtles are continuing and are important components of management of the species (Kat Beal, U.S. Army Corps of Engineers, pers. comm.).

Age & Growth

Few data are available concerning growth or growth rates of western pond turtles. Storer (1930) discussed growth in relation to the number concentric ridges (= annuli) seen on the scutes. Storer presented data on 15 specimens from California ranging in size from 27.8 to 95.0 mm and 2-5 years in age. He stated that in other aquatic turtles such as painted turtles (*Chrysemys picta*), annuli may be worn away on older individuals. He added that up to 12 annuli could be distinguished on "middle-sized" individuals. Storer inferred that the age of an individual (in years) would be less than or equal to the number of annuli visible, even in the event that more than one ring accrued during any given year.

This reasoning seems flawed given that rings may become indistinguishable in older turtles. Based on data for 17 captive, adult western pond turtles (five females and 12 males), Storer concluded that the growth rate of western pond turtles was greater than that of western painted turtles, as described by Agassiz (1857). This conclusion is probably inaccurate because at least six of the 17 individuals Storer examined were described as having an indefinite number of rings. According to Storer's account, the disappearance of the oldest annuli in at least three individuals and three others having had at least one more annulus than was used in determination of age may have inflated the growth rates calculated.

Holland (1991) also discussed the relationship between annuli and age. He contended that annuli and relative size fairly represent age up to about 5-7 years. Based on unpublished data, Holland added that western pond turtles exhibit significant differences in growth rates between and among populations, particularly after the third year. He asserted that the age of turtles older than 5-7 years can only be approximated because of the aforementioned sources of variation and annuli loss through wear.

Holland (1991) also addressed juvenile and adult growth. Holland found that, across their range, western pond turtles grew the most rapidly in the 1-6 year age range, and growth slowed considerably after the seventh to eighth year. Holland determined that turtles on the Central California Coast grew an average of 3.2 mm/month during their first year, slowing to approximately 2-3 mm/year after the eighth year.

Survivorship

Juvenile western pond turtle survivorship has become an important issue relative to the conservation of the species. Jennings et al. (1992) contended that, in addition to or as a result of environmental factors, survivorship is too low to maintain population levels given the low fecundity of the species. Hence, western pond turtles have experienced a reduction in geographic range and declines in abundance of many populations.

The western pond turtle is thought to be long-lived. Adult turtles, originally captured and marked during the 1960s and recently recaptured, yielded estimated ages of 45-50 years (Holland, pers. comm.). Holland (1991) and Bury (pers. comm.) have reported anecdotal accounts of western pond turtles recaptured 30-50 years after they had originally been marked as mature adults. These values are probably not age maxima.

Western pond turtles also seem to experience relatively low annual turnover rates as adults, estimated at 3-5 % across all populations (Holland 1991). Holland (1991) speculated that turnover rates might be higher in the northern portions of the range and at higher altitudes than in southern portions of the range or lower elevations, but he offered no explanation for the potential cause of this pattern. Holland also thought that adult female western pond turtles may exhibit higher mortality than males, arguing that females were more vulnerable to predation during nesting excursions. He observed sex ratios varied from a high of 4:1 (males:females) to 1:2. Bury (1970) observed a 1:1 ratio on Hayfork Creek, whereas Holland (1985a) found a ratio of about 2:1 on the Central California Coast.

Based largely on data presented in Holland (1991), Jennings et al. (1992) estimated mortality in juvenile western pond turtles at 88-92%. They asserted that high juvenile mortality, low nest success (see Reproduction section), and human-induced environmental factors (e.g., degraded habitats, introduced predators, isolation due to development, reservoirs and dams) have severely reduced recruitment.

The adult bias in western pond turtle populations may be typical of turtle populations in general. Bury (1979) observed that in most populations juveniles appeared to comprise a variable but low proportion of the population, whereas the proportion of individuals presumed to be mature was high. Populations may vary in the severity of adult bias, which has the potential of reflecting serious recruitment problems. Existing data on juvenile mortality and adult-biased populations lack the resolution to distinguish the extent of recruitment problems that may be concealed among populations.

THREATS TO SURVIVAL

Habitat loss

The primary threat to the western pond turtle is habitat loss. Habitat losses have affected each stage of the turtle's life cycle. Alterations of terrestrial habitat have reduced available nesting habitat and exposed existing, often less than optimal, nesting areas to additional threats (e.g., increased exposure to predation, trampling, and inundation). Appropriate terrestrial overwintering habitat has also been lost. Aquatic conversions have reduced juvenile rearing habitat, basking areas, in-stream pools, and other necessary

habitat. The extent of these losses is erratically described throughout the range, and the overall effect on the species has not been established. The occurrence of the western pond turtle in degraded or human-made habitats (e.g., reservoirs, sewage treatment ponds, irrigation canals, and others) complicate assessment of habitat loss, especially because the species is long-lived. Individuals may persist for decades in habitats where nesting habitat has long been eliminated.

Terrestrial habitat losses are linked to agricultural, residential, silvicultural, and urban development. Crop farming may either destroy nests annually in otherwise suitable habitats or promote a habitat structure that prevents nesting, particularly adjacent to streams and ponds. Irrigation practices may drain aquatic habitat and create channelized ditches, lacking suitable adjacent nesting areas. Development of residential areas along water bodies removes nesting habitat, and the infusion of constant human disturbance further impacts turtles that remain. Transformation of undeveloped forests to commercial forests, and some silvicultural practices reduce or eliminate potential overwintering habitat at moderate elevations (ca. 300-900 m [1000 - 3000 ft]). Most of these impacts are most evident in and around urban areas. Habitat losses are most conspicuous in Oregon around cities such as Medford, Klamath Falls, Roseburg, Eugene, Salem, Corvallis, and the greater Portland Metropolitan Area.

Sedimentation, loss of pool-building structures (e.g., boulders and large woody debris), channelization, and the increased flood potential associated with timber harvest activities have probably also reduced aquatic habitat available to the species. Increased

sedimentation may be directly related to ground disturbance from timber harvest or result from road building. Pools used by turtles for basking and foraging (Bury 1970) can be reduced and degraded by sedimentation. Increased channelization to stabilize land uses (e.g., transportation, timber production, agriculture, and other development) reduced sinuosity and decreased numbers of in-stream structures, thereby reducing formation of pools (FEMAT 1993). Substantial losses (41-94%) in the frequency and depth of large, deep pools ($>42 \text{ m}^2$ [50 yds^2] and $>1.8 \text{ m}$ [6 feet] deep) have been recorded in selected streams on national forests in western Washington and coastal Oregon (FEMAT 1993). Comprehensive analysis of losses across the elevational range of the western pond turtle has not been attempted, but similar losses have probably occurred in southwestern Oregon and the Oregon Cascades. Flooding linked to timber management techniques (e.g., clearcutting, regeneration harvest, shelterwood harvest, some salvage) has the potential to scour in-stream turtle refugia. Such flooding is often aseasonal, (late spring-summer) a historically rare event (Ligon et al. 1995), and turtles returning to streams in spring are likely more vulnerable to their effects. In northern California, aseasonal flooding has occurred as a result of upstream reservoir releases, which is linked to turtles reducing instream time until water velocities decrease and water temperatures increase to levels typical of historic conditions (Reese 1996, Reese and Welsh 1998). Impacts of such temporal shifts in flow pattern on northwestern pond turtles in Oregon are probably similar.

Agricultural development (e.g., seed and crop production, livestock production, nursery) is a major and continuing cause of upland habitat loss in Oregon, particularly at lower elevations (< 300 m), where it is often the predominant land use. Alteration of historic flood and river flow patterns for agricultural production has reduced riparian areas and diminished hydrologic coupling with upland areas (Sedell and Froggatt 1984) that are used by western pond turtles for nesting and overwintering. Although the effects of reducing riparian areas and their pattern of hydrologic coupling to upland areas have not been studied specifically for their effects on western pond turtles, those effects are likely to be negative. The valley bottom was once covered in grasslands, savannahs, and wet prairies (Holland 1994; Bowen 1968). Most of this area has been converted to agriculture, which has probably eliminated or degraded areas that were once suitable for nesting and overwintering.

Besides conversion of terrestrial habitat turtles use to agricultural land, practices associated with increasing agricultural productivity have also eliminated or degraded suitable aquatic habitats. Applications of fertilizers, pesticides, and other agricultural chemicals are known to reduce water quality (Altman et al. 1997; Anderson et al. 1997) and may affect western pond turtle habitat. In addition, studies have shown that some of these compounds have marked physiological effects on alligator (*Alligator mississippiensis*) and turtle eggs in the laboratory (Gross and Guillette 1993), as well as on the reproductive physiology of alligators in Florida lakes (Guillette et al. 1993). Effects of contamination consisted of 25-35 percent reduction in hatching success,

abnormal levels of estrogen and testosterone, abnormal development and permanent modification of gonads, and poor reproductive success (Gross and Guillette 1993; Guillette et al. 1993). Whether western pond turtles have been similarly affected by agricultural chemicals is unknown; the U.S. Fish and Wildlife Service has initiated studies addressing this issue in Oregon (Elizabeth Materna, U.S. Fish and Wildlife Service, pers. comm.).

Impoundment, diking, and ditching associated with irrigation have probably had profound effects on the availability and suitability of aquatic habitats within the range of the western pond turtle. The primary result of these practices is thought to be the loss or deterioration of aquatic habitat through a variety of mechanisms, which include, but are not limited to reduction in size, number, and connectivity of water bodies; loss of aquatic vegetation; loss of prey species, and removal of structures (e.g., woody debris, snags, brush) necessary for thermoregulation and cover (Holland 1991; Jennings et al. 1992). The details of how these mechanisms may influence habitat loss for western pond turtles have not been experimentally addressed.

Dams are a common feature of many streams throughout the range of the western pond turtle. Holland (1991) hypothesized that dams had a suite of adverse impacts on western pond turtles, which included:

- 1) elimination of existing turtle habitat by dam and reservoir construction;
- 2) creation of aquatic habitat unsuitable for pond turtles;
- 3) creation of habitat suitable for exotic predators and/or competitors;

- 4) introduction of exotic predators or competitors in reservoirs;
- 5) introduction of higher levels of human disturbance, primarily from recreation in reservoirs;
- 6) adverse alterations of flow regimes, temperature regimes, and in-stream habitat downstream from dams; and
- 7) cessation of upstream-downstream and in-reservoir movements due to unsuitable habitat between occupied locations.

Some of the effects of dams on northwestern pond turtles in the Trinity River Basin, Trinity County, California were examined from 1991 to 1995 (Reese 1996; Reese and Welsh 1998). They found that dams had several impacts on distribution, behavior, and habitat of western pond turtles. Within Lewiston Reservoir on the Trinity River, Reese found the following:

- 1) turtles in low density,
- 2) lack of suitable turtle habitat (i.e., "deep, pooled water with abundant basking sites and underwater cover objects"),
- 3) lower than preferred water temperatures, and
- 4) extremely adult-biased populations.

Turtle presence in the reservoir was positively correlated with higher water temperatures and increased human presence. The correlation between human and turtle presence was thought to be related to fishing activity by both humans and western pond turtles. Reese

also suggested that, although the correlation was significant, the association may be the result of a third unmeasured variable.

Downstream from the reservoir, Reese observed other effects on turtles and turtle habitat, including:

- 1) changes in the cross-sectional conformation of the channel from shallow water edges and side channels to deep, swift water;
- 2) sedimentation of deep pools;
- 3) loss of seasonally flooded marshes;
- 4) reduced water temperatures; and
- 5) increased homogeneity of vegetation.

The aforementioned changes were concluded to be the result of altered flow regime from upstream dams, and these alterations induced changes in turtle behavior (Reese 1996; Reese and Welsh 1998). Turtles, particularly juveniles, were observed to leave or avoid the mainstem portions of the river in an apparent attempt to seek warmer and slower water in adjacent vernal pools, ponds, oxbows, and wetlands.

Residential and urban development is the most rapidly growing land use in Oregon. In the most recent summary available, the human population in Oregon increased an estimated 7.9 percent (Table III). Although other parts of the state are growing more rapidly, most counties within the range of the western pond turtle are already the most populated and are continuing to experience substantial increases,

TABLE III
HUMAN POPULATION INCREASES IN OREGON,
1980-1990 (CENSUS DATA CENTER, 1996).

	1980 Population	1990 Population	% Increase
Counties within the range of the western pond turtle	2,235,473	2,354,677	5.3
Willamette Valley	1,742,047	1,913,688	9.9
Umpqua Drainage	93,748	94,649	1.0
SW Oregon	272,350	288,638	6.0
Klamath	59,117	57,702	-2.4
Oregon	2,633,105	2,842,321	7.9

particularly in the Willamette Valley (Census Data Center 1996). These population increases have resulted in a corresponding increase (11.4 percent) in housing units across the state between 1980-1990 (Census Data Center 1996). These increases imply that habitat available to western pond turtles (as well as other native species) is decreasing as a result of conversion of rural areas to urban and suburban developments.

Overutilization for commercial, recreational, scientific, or educational purposes

Western pond turtles have been used for commercial purposes, in the past for food, and more recently for the pet trade. Capture and sale of thousands of western pond turtles for use in the restaurant industry was common in the late 1800s to early 1900s (Holland 1991). One account describes a schooner used to harvest western pond turtles

from Tulare Lake, Kings County, California, now mostly dry from water use in Central and Southern California. Holland (1991) reports captures frequently exceeding 11,000 kg (24,000 lb) with a peak of 48,972 kg (107,869 lb) harvested in 1899. The estimated average weight was 908 g/turtle (age 15+ years) between 1888-1892 (Holland 1991). Such extensive collection of older animals had direct and cumulative effects on the breeding populations in the areas of collection, and turtles at some historic collection sites have long since been extirpated. Anecdotal accounts of the observations of trappers allude to the existence of commercial trapping efforts in Oregon (Storer 1930). Holland (1993b) also stated that turtles were collected in Oregon for Portland restaurants as late as the 1950s.

Commercial trade of western pond turtles is illegal in Oregon, Washington, and California. However, sale of the species has been documented in many other parts of the United States. Holland (1993b) observed the species listed in 1991 on reptile dealers price lists for sale at \$125.00. The current extent of collection and commercial trade of western pond turtles is unknown.

Disease or predation

Incidents of disease have occurred within the range of the western pond turtle. In at least one case, an outbreak of an unknown pathogen which causes upper respiratory disease (URD) depleted approximately 40% of a population in Washington. In 1996, 24 turtles were found dead or dying at Alligator Lake, Douglas County, Oregon, less than three miles from Carmine Lake, the site of this study. Necropsies were completed on all

dead individuals, but the cause of the disease remains unknown (Elliot Jacobsen, DVM, University of Florida, pers. comm.). Although additional remains were found in 1997, no recently deceased turtles were found and live captured turtles exhibited no continued signs of disease.

Other natural or man-made factors affecting its continued existence

Numerous structures serve as barriers to pond turtle movement. Roads are commonly built parallel to streams. Turtles are seasonally observed crossing roads in Oregon, presumably in search of "overwintering" habitat or oviposition sites. Vehicular mortality is common (Cindy Barkhurst, pers. comm.). Railroads also block movements of turtles and can trap turtles between rails. Dead turtles, lacking obvious injury, have been found between railroad tracks; exposure or dehydration presumably caused death (Holland, pers. comm.).

Toxic spills have been known to cause injury and death to western pond turtles. Diesel fuel spills have occurred in California and Oregon which have had documented detrimental effects on western pond turtles. Bury (1972b) noted a dead turtle and other diesel-affected turtles after a train derailment and subsequent diesel spill into Hayfork Cr., Trinity County, California. In January 1993, a train derailed in southwestern Oregon, causing 6,100 gal. of diesel fuel to spill into Yoncalla Creek, Douglas County, Oregon, a tributary of Elk Creek (USDI 1993b). A detailed analysis of the effects of the fuel on contaminated western pond turtles was conducted and compared to unaffected western pond turtles. Turtles exposed to diesel fuel ($n = 30$) were captured after the spill occurred

and treated for observed health problems, ranging from minor skin lesions to more serious systemic problems. Major adverse conditions reported in affected turtles included: eye problems (from inflammation to blindness, $n = 10$), skin problems (reddened sloughing skin, $n = 23$), bruised plastron ($n = 20$), shell rot ($n = 15$), septicemic cutaneous ulcerative skin disease (SCUD) ($n = 11$), and loss of claws ($n = 26$) (USDI 1993b). One turtle was euthanized after failing to respond to treatment. Necropsy on this turtle revealed numerous conditions resulting from exposure to diesel fuel: pneumonia; hepatic inflammation; severe chemical burns; secondary bacterial infections of the eyes, sinus/upper respiratory system, and dermis; necrosis of the head; and cutaneous ulcers (USDI 1993b). Three females captured laid a total of 19 eggs, 8 of which hatched and produced healthy hatchlings (USDI 1993b).

Toxic spills are likely to occur sporadically, negatively affecting western pond turtles. Many streams inhabited by turtles parallel railroads and highways on which accidents involving chemicals occur with some frequency. Based on data between January 1988 and June 1996, an annual average of 203 toxic spills were reported in Oregon. In 1995, 391 spills reported to DEQ reached surface water (Mike Zollitsch, Oregon Department of Environmental Quality, pers. comm.). This type of spill is most likely to adversely impact western pond turtles. Most spills that reached water were petroleum (56%); the remaining spills consisted of sewage (31%), chemical agents (10%) and other unspecified substances (3%). Given the sensitivity of turtles to some

contaminants, particularly petroleum products, spills may have catastrophic effects on local turtle populations.

Incidental injury from fishing and related activity has been observed in western pond turtles from a variety of locations across their range (Holland 1991). Holland (1991) estimated that 3.6 % of the turtles captured at a site in Oregon and 6 % of the turtles captured at a site in the Southern Sierra Nevada exhibited signs of trauma from fish hooks or had ingested fish hooks. Captured turtles that had ingested fish hooks were reported to be "below normal weight," and some were found dead with "hooks imbedded in the esophagus or stomach wall" (Holland 1991). In April 1993, the Bureau of Reclamation (Mark Buettner, pers. comm) reported that three western pond turtles drowned in nets used to census fish populations in the Klamath Basin.

Turtles are occasionally shot with firearms. Turtles are sometimes found with bullet holes in their carapace, and some biologists have provided anecdotal accounts of turtles being shot, presumably for target practice (Holland 1991, Barkhurst, pers. comm.).

Western pond turtles still occur within most of their historic range and may persist in sites where they are currently extant because they are long-lived. Although western pond turtles may persist at sites throughout their range, their normal activity patterns and ability to reproduce may be interrupted because of the threats to the species. The loss of these features over the range of the western pond turtle would likely lead to the reduced abundance and localized extirpations seen today. Without management to maintain this habitat, western pond turtles may eventually be lost within much of their

range. This paper addresses selected aspects of western pond turtle biology in a pond in southwestern Oregon. Information obtained on seasonal use of aquatic habitat, active-season movement patterns, and aspects of population structure may help to elucidate turtle ecology in an undisturbed stillwater habitat and provide management direction.

SITE DESCRIPTION

SOUTH UMPQUA DRAINAGE

The study region, the South Umpqua Basin, lies mostly within Douglas County, Oregon (Figure 4). The South Umpqua River, a sixth-order stream that joins the North Umpqua River west of Roseburg, drains this 4,564-km² basin (1,762 mi²) (USACE 1971). The basin ranges in elevation from 110 m (360 ft) to 2066 m (6,780 ft) (USACE 1971).

Topography of the upper basin is relatively steep. Above Tiller (river mile 187), the South Umpqua River flows through an incised, rocky canyon. Reaches in the upper basin are a mosaic of pools, riffles, runs, cascades, and waterfalls. The substrate is mostly coarse, ranging from bedrock and boulders to gravels. Most of the upper basin is within the Tiller Ranger District of the Umpqua National Forest. Timber production and recreation are the predominant land uses. During the summer months, the river above Tiller is popular for swimming and sportfishing.

In contrast, the lower basin has a gentler topography. Below Tiller, the South Umpqua River flows through a wide valley with an increasingly shallow gradient. Finer substrates (mud to sand) increase, whereas coarser substrates decrease, especially downstream of Milo. Land in the lower basin is mostly privately owned, and agriculture, light industry, and rural residences are the predominant land uses.

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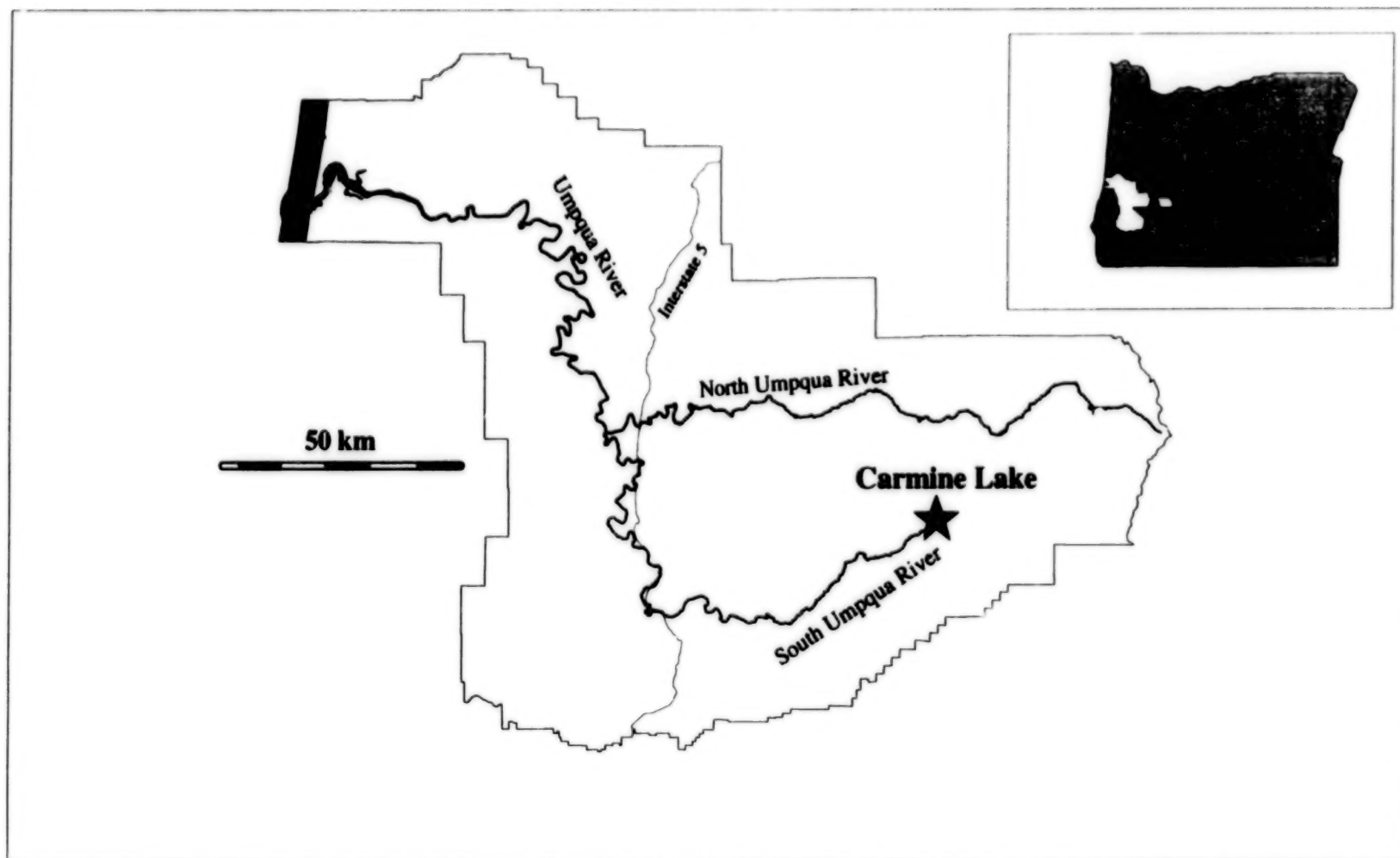


Figure 4. Map of the South Umpqua Drainage.

57

Franklin and Dyrness (1972) placed the vegetation of the upper basin within the mixed-conifer zone. Douglas-fir (*Pseudotsuga menziesii*), sugar pine (*Pinus lambertiana*), Ponderosa pine (*Pinus ponderosa*), incense-cedar (*Libocedrus* (= *Calocedrus*) *decurrens*), and white pine (*Abies concolor*), with lesser numbers of western red cedar (*Thuja plicata*) dominate the overstory. Vine maple (*Acer circinatum*), western yew (*Taxus brevifolia*), prince's pine (*Chimaphila umbellata*), and salal (*Gaultheria shallon*) are prominent in the understory.

The upper South Umpqua Basin appears to support greater numbers of *C. m. marmorata* than the lower basin (Holland 1992). However, northwestern pond turtles appear to be patchily distributed throughout the drainage with nodes of what may represent a metapopulation system occurring disjunctly in the river and associated lakes and tributaries (Holland 1992). Patchiness of turtles in the upper basin may largely be the result of the mosaic nature of available habitat (i.e., disjunct ponds or groups of ponds, instream pools, nesting areas). However, in the lower basin, land use and the expanding human population may have decreased western pond turtle numbers, and as a consequence, distances among remaining populations may have increased.

STUDY AREA

The study site, Carmine Lake, is located ca. 39 km (24 mi) northeast of Tiller on the Tiller Ranger District, Umpqua National Forest. Carmine Lake is a small lake (2 ha [5 ac]) located ca. 0.5 km west of the Black Rock Fork of the South Umpqua River (Figure 5) in Township 28S, Range 2E, SE ¼ Sec. 21.

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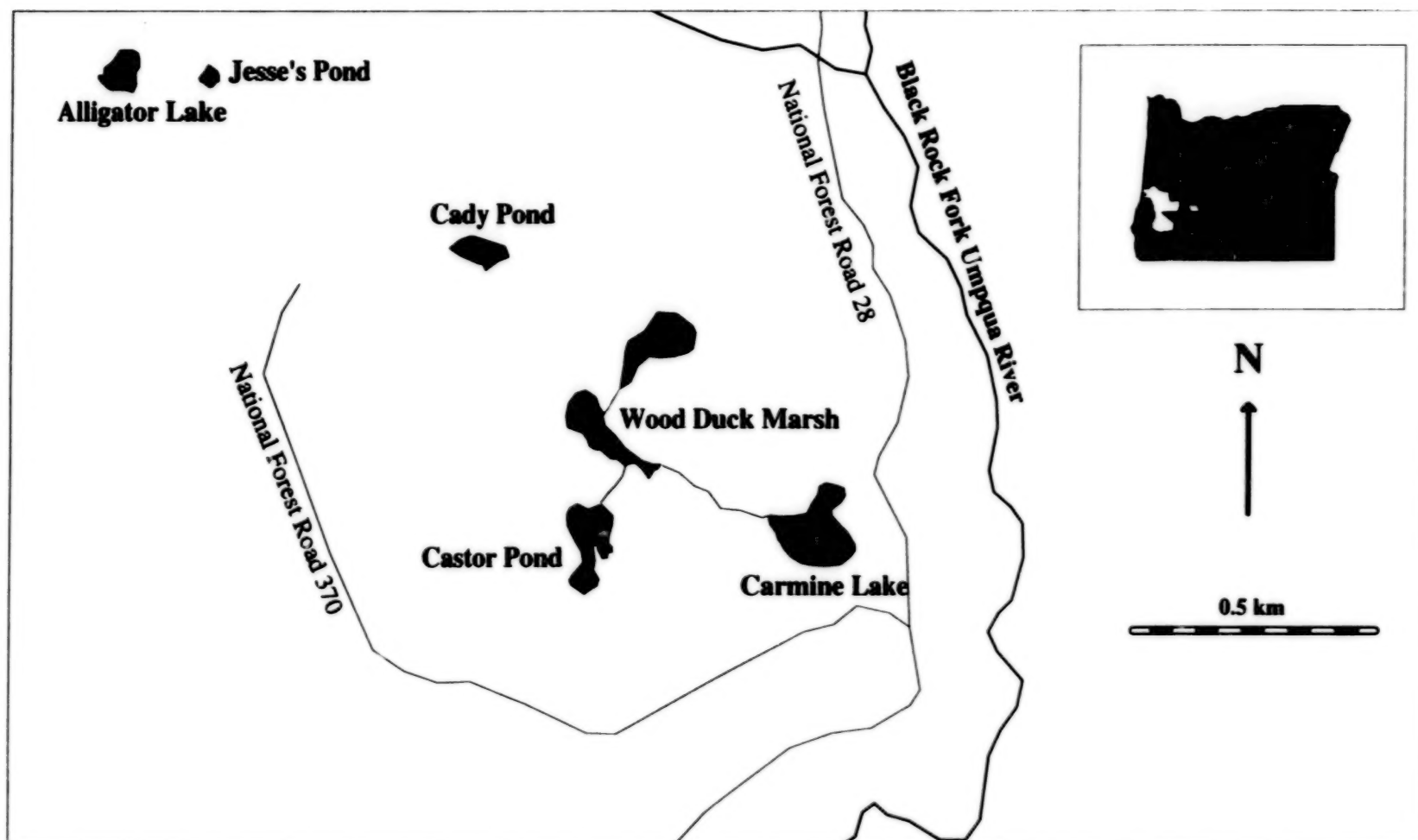


Figure 5. Map of the study area, Carmine Lake, Douglas County, Oregon.

The area immediately surrounding Carmine Lake is thought to have been influenced by complex land flows. The area has many small lakes, ponds, and marshes, some of which are connected by surface water, whereas the subsurface pattern of hydrological connections are unknown. A small, permanent creek connects Carmine Lake to Wood Duck Marsh, ca. 1 km to the northwest. Wood Duck Marsh receives surface inflow from Castor Pond, located 1.2 km west of Carmine Lake (Figure 5). A series of smaller ponds lie upslope to the northwest of Wood Duck Marsh.

The outlet of Carmine Lake is on its south side and flows over an old beaver dam. In 1974, this dam was reinforced with silty clay dredged from the bottom of the lake (USDA 1976). The purpose of the dredging was to provide deeper water for stocked trout (Cindy Barkhurst, Umpqua National Forest, pers. comm.).

At approximately 730 m (2400 ft) of elevation, the depth of Carmine Lake varies seasonally over about a one meter range. The maximum depth varies seasonally and is approximately three meters at full pool at the deepest point (southeast side).

Floating and submerged woody debris including logs, snags, and stumps are scattered across most of the lake, except on the east end, covering approximately 5% of the water surface. Emergent vegetation is present primarily along the north and northwest margins of the lake or on logs, snags, or stumps in the lake. Much of the woody debris is vegetated with sedges, rushes, and grasses. In spring 1993, two large logs were anchored in the center of the lake. They were bare of vegetation and bark. One active beaver lodge was located along the south shore. Aquatic vegetation (Table IV) present varies seasonally with weather conditions. Star duckweed (*Lemna trisulca*) often

covered at least 75% of the water surface during the 1992 and 1993 summers. Pond lily (*Nuphar polysepalum*) occurs in patches in the middle of the lake during summer, and pondweed (*Potamogeton alpinus*) sparsely covers the south end of the lake in areas > 2 m depth. Wapato (*Sagittaria latifolia*) occurs infrequently in some areas. Considerably less (=50% coverage) floating vegetation was present in 1995 than during the study period, 1992-1993. In winter, the lake often freezes over, the vegetation dies back, and the water depth increases enough to submerge most logs.

TABLE IV
COMMON AQUATIC VEGETATION PRESENT IN CARMINE LAKE

Vegetation type	Common Name	Scientific Name
floating	Star (ivy) duckweed	<i>Lemna trisulca</i> L.
	Pond lily	<i>Nuphar polysepalum</i> Ait.
	Pondweed	<i>Potamogeton alpinus</i> Balbis
emergent	Sedges	<i>Carex</i> sp.
	Rushes	<i>Juncus</i> sp.
	Grasses	Poaceae
	Wapato, broadleaf arrowhead	<i>Sagittaria latifolia</i> Willd.
	Cattails	<i>Typha latifolia</i> L.

Vegetation surrounding the lake consists mainly of species found in the mixed conifer zone (Franklin and Dyrness 1972). Based on plants present at the lake (Table V), the site best fits the characteristics of a low-elevation, warm, dry environment when compared to other sites described for the South Umpqua Basin (Minore 1972).

TABLE V

UPLAND VEGETATION COMMONLY FOUND AT CARMINE LAKE, OREGON

Canopy	Common Name	Species
Understory	Manzanita	<i>Arctostaphylos columbiana</i> Piper
	Chinquapin	<i>Castanopsis chrysophylla</i> Dougl.
	Western prince's pine	<i>Chimaphila umbellata</i> var. <i>occidentalis</i> (Rydb.) Blake
	Salal	<i>Gaultheria shallon</i> Pursh.
	Twinflower	<i>Linnaea borealis</i> L.
	Grasses	Poaceae
	Bracken fern	<i>Pteridium aquilinum</i> (L.) Kuhn
	Western rhododendron	<i>Rhododendron macrophyllum</i> G. Don
	Spirea	<i>Spirea douglasii</i> var. <i>douglasii</i> Hook.
Overstory	Grand or white fir	<i>Abies grandis</i> (Dougl.) Forbes
	Madrone	<i>Arbutus menziesii</i> Pursh.
	Incense cedar	<i>Calocedrus decurrens</i> (Torr.)
	Sugar pine	<i>Pinus lambertiana</i> Dougl.
	Ponderosa pine	<i>Pinus ponderosa</i> Dougl.
	Douglas fir	<i>Pseudotsuga menziesii</i> (Mirbel) Franco
	Western cedar	<i>Thuja plicata</i> Donn.

Many wildlife species occur in the vicinity of Carmine Lake (See Appendix A-1).

Rainbow trout (*Oncorhynchus mykiss*) and mosquito fish (*Gambusia affinis*) have been introduced to the lake since at least the early 1970's, and fingerling-sized trout continue to be stocked each spring and summer (C. Barkhurst, pers. comm.). No native fish species have been observed in the lake, and fish were probably historically absent.

Several species of amphibians and reptiles were recorded at Carmine Lake.

Pacific treefrogs (*Hyla regilla*) were abundant around the lake. Based on observations of their eggs, northwestern salamander (*Ambystoma gracile*) and rough-skinned newt

(*Taricha granulosa*) were also present in Carmine Lake during the study period. Several lizard and snake species were commonly seen over the study interval (Appendix A-1).

Several bird species frequented the immediate area. Red-winged blackbirds (*Agelaius phoeniceus*), red-breasted sapsuckers (*Sphyrapicus ruber*), pileated woodpeckers (*Dryocopus pileatus*), and wood ducks (*Aix sponsa*) nested at Carmine Lake in 1992. Wood ducks "families" were often seen roosting on turtle basking logs, sometimes with turtles on the same log. Great blue herons (*Ardea herodias*), a potential predator on western pond turtles, were observed wading in shallow areas, and osprey (*Pandion haliaetus*) occasionally flew over the lake.

Mammals in the vicinity of the lake included gray fox (*Urocyon cinereoargenteus*), black bears (*Ursus americanus*), raccoon (*Procyon lotor*), bobcat (*Lynx rufus*), and striped skunk (*Mephitis mephitis*). River otter (*Lutra canadensis*), coyote (*Canis latrans*), and mountain lion (*Felis concolor*), all of which were observed within a 1.6 km [1 mi] radius of Carmine Lake, probably also frequent the area. All of these species are known turtle predators. Beaver (*Castor canadensis*) at least partly created the lake; their presence is revealed by gnawed saplings and the previously noted lodge on the south shore on which both fresh and old logs existed.

Invertebrates are seasonally abundant in the lake. Dragonflies and damselflies are common in the late spring and summer. Various invertebrates and invertebrate larvae are common food for western pond turtles. At least one species of aquatic snail is also common in the lake.

Carmine Lake receives limited human use (See Appendix B). Some littering, illegal campfire construction, and illegal shooting occur around the lake. Because of its remote location and difficulties with regulatory enforcement, these activities occur despite U.S. Forest Service efforts to educate through signage and information dissemination programs.

MATERIALS AND METHODS

CAPTURE

Turtles were captured manually or trapped between May and October, 1992-1993. Turtles were captured over five intervals in 1992 and eleven intervals in 1993. Data from additional capture periods, conducted 1987-1989, 1991, and 1995 were also used. Selected turtles were held for one to five days, until at least six males and six females >120 mm had been caught in order to equip them with radio transmitters.

Manual captures were made while snorkeling. The captor swam around the lake, checking likely refugia (logs, vegetation clumps, undercut banks) and open water visually and manually. Captured turtles were then handed to an assisting observer, who followed the captor from the shoreline or in a small, non-motorized boat. Any assisting observer remained within areas already surveyed to minimize disturbance of unsampled areas. The captor's entry and exit times to and from water. For each capture, the time of capture, estimated water depth at the capture point, and estimated distance to the nearest shoreline from the capture point were recorded.

Turtles were also captured using single-opening, 10-mm nylon mesh traps (Figure 6). Traps were placed at an angle deep enough to submerge the trap while providing an air pocket large enough for trapped turtles to breathe. Traps were placed within 1 m of known basking sites and/or refugia, and tied to shore for easy access while

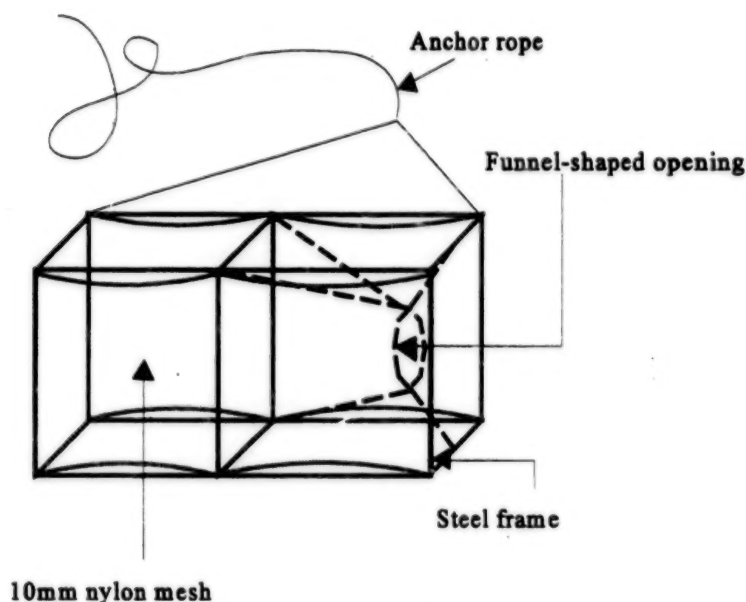


Figure 6. Schematic diagram of single-opening funnel trap used to capture turtles.

making certain that they were camouflaged from public view with aquatic vegetation. Aluminum cans of oil-based herring, perforated to allow the oil to seep out, were used as bait. Bait was typically changed weekly. Traps were checked for captured turtles at intervals ranging from four to twelve hours.

Captured turtles were processed on the capture date. Processing consisted of: 1) sexing; 2) measuring; 3) marking; 4) noting previous identification numbers and/or physical anomalies (if any); 5) palpating females to detect eggs; and 6) in some cases, attaching transmitters. Carapace length, measured with calipers to the nearest 1.0 mm, was the standard size measurement taken on all turtles. Unmarked turtles were given a unique mark by notching marginals with a triangular file. Details of the method, described in Holland (1991), are based on a number coding system slightly modified from the method of Cagle (1939). Following processing, turtles were retained in clean

buckets until release. During captivity, turtles were protected from thermal stress and routinely rehydrated.

Females were examined to determine whether they were gravid. Examination consisted of palpating for eggs under the inguinal shields in front of the extended posterior limbs using both index fingers. Females with eggs were x-rayed to determine clutch size (Gibbons and Greene 1979).

Mark and recapture data were used to determine population size using the Bailey estimate (Begon 1979), modified from the Peterson Index (Seber 1973). Numbers of males, females and juveniles were compared using Chi-square tests. Recaptured turtles' growth rates were calculated by subtracting initial CL from the CL at second capture and dividing by the number of days between captures. This rate was multiplied by 365 to obtain the annual growth rate. These data were analyzed with a simple exponential regression using Statgraphics® (Manugistics 1993).

VISUAL OBSERVATION

Counts of turtles active at the water surface were taken at 1000 and 1400 hr each day, generally the optimum basking times for western pond turtles (Holland 1991). Counts were done using a 15x-45x spotting scope and binoculars. Individuals with transmitters, identified by transmitter colors, were recorded when seen. Additional counts were taken and conditions recorded if marked changes occurred in the numbers of visible turtles throughout the course of a day (i.e., unusual or sudden weather changes occurred, humans or dogs visited after which basking ceased).

Environmental conditions including temperature and weather were also recorded during the twelve-hour periods. Due to equipment failures and loss at the study site, the U.S. Forest Service provided atmospheric data (air temperature and precipitation) used for analysis. These data were obtained from the remote sensing station at Black Rock Remote Climate Station approximately 9 km (6 mi) northeast of the study site.

TELEMETRY

Telemetry was conducted on turtles ≥ 130 mm CL because transmitter weight and adhesive might adversely affect smaller turtles (Holland, pers. com.). Initially, six male and six female turtles were equipped with transmitters. Two of the six transmitted females were gravid and were tracked to attempt to detect nesting activity. In the course of the study, one of the transmitted males died of unknown causes and three males left Carmine Lake. Two additional turtles, one male and one female, were later equipped with transmitters. A total of 14 turtles, seven of each gender, were transmitted.

Hand held receivers (model TR-2-E, includes optional 4-MHz extended frequency range [150.000 - 154.000 MHz], Telonics®, 932 East Impala Avenue, Mesa, Arizona 85204) with an H-shaped antennae (model RA-2A, Telonics®), were used to track transmitter-equipped turtles. In rainy weather, receivers were protected with plastic bags. Rechargeable battery packs were used with the receivers and recharged once a week or as needed.

Transmitters (model SM1-Hs, AVM Instrument Company, Ltd., 2356 Research Drive, Livermore, CA 94550) emitted pulses in the 150.000-153.000 MHz frequency

range. Individual transmitters were tuned to emit at frequencies at least 0.040 MHz apart. Transmitters were color-coded with Plasti-Dip® (PDI, Inc. P.O. Box 130, Circle Pines, MN 55014-0130), a retail product usually used to cover handtool grips. Plasti-Dip® made the transmitters more visible, more water-resistant, and helped to differentiate individuals visually.

Transmitters were fixed onto the carapace of each turtle using five-minute epoxy (brands as available) (Figure 7). In 1993, dental adhesive was used rather than epoxy because in 1992, at least one transmitter at Carmine Lake and several others at other locations were lost, probably because the epoxy softened and failed with age and exposure to sunlight. After the transmitter was bonded to the carapace, the entire unit



Figure 7. Transmitter fixed on the carapace of a male northwestern pond turtle (174.5 mm CL).

(transmitter and antenna) was covered with epoxy to reduce snagging and decrease friction from water resistance. Turtles equipped with a transmitter were released within 10 m of the location at which they were captured.

Locations of each turtle were determined every two hours for twelve-hour periods between 0800 and 2000 hr each day. Turtle locations were recorded on acetate sheets over an aerial photograph of the lake. The locations were marked with the turtle number and whether the location was visually confirmed. A 10 m x 10 m grid was established for the lake to identify turtle positions (Figure 8).

Triangulation (White and Garrott 1990), was used to determine turtle locations. The intensity control on the receiver was set at four and the signal intensity was recorded at the same time the locations were recorded. Signal intensity was rated on a scale of one (inaudible) to five (loud enough to be uncomfortable to the ears with a headphone attachment). On a sweep, the loudest signal indicated the bearing of the signal direction at a fixed point. After an initial bearing was established at one point, the observer moved to a new point at least 20 m away to establish a second bearing. Intersection of the two bearings determined turtle location, assuming the turtle had not moved during the interval when bearings were established.

Home Range

Aquatic home range was determined by mapping the telemetered locations of turtles on the grid pattern (White and Garrott 1990). A surface plot was made to illustrate the occurrence frequency of each turtle across the lake. Highest plotted elevations on a

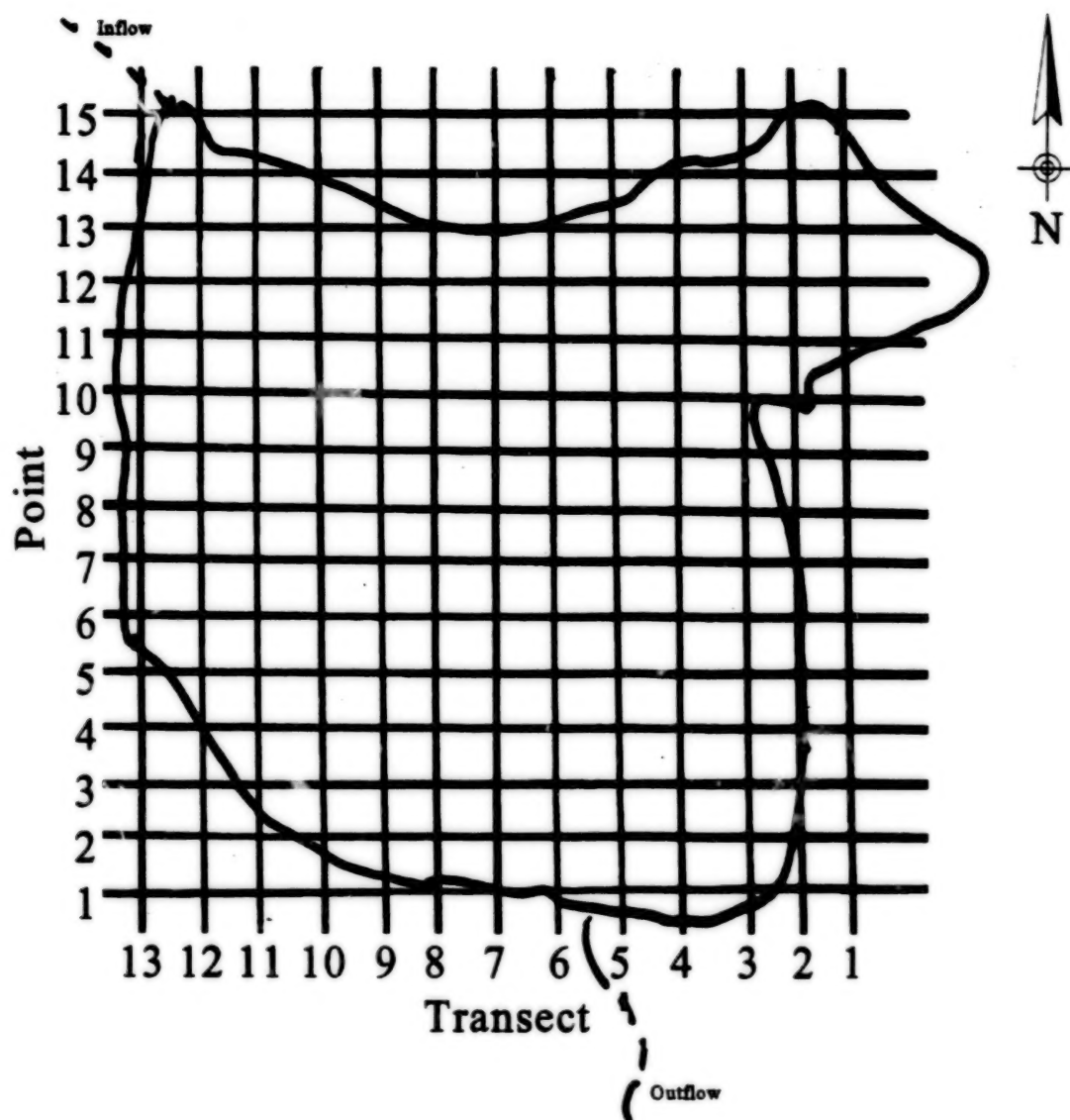


Figure 8. Grid system used for determining radio-tracked turtle locations and to characterize habitat.

surface plot indicated where each turtle was located most often. Overlaying the surface plot on a diagram of the lake provided the spatial use and frequency of occurrence within the lake. The area covered by each turtle's home range was determined by summing the area of each square of the grid (100 m²) (Figure 8) in which a turtle occurred one or more times (White and Garrott 1990).

Active-season Movement Patterns

Minimum bi-hourly, daily, and overnight movements were calculated from the telemetry data. Minimum distances moved were calculated using the grid system (Figure 8) (White and Garrott 1990).

Minimum Movements over Two-hour Intervals. The minimum distances moved over two-hour intervals (bi-hourly movements) were calculated between an initial location for each individual and a location recorded two hours later. Average minimum bi-hourly movements were calculated for each individual. The mean, standard deviation, and standard error were calculated and compared for each individual, for males as a group, for females as a group, and for all turtles for the length of the study period.

Minimum Movements over One-day Intervals. Two types of daily movements were calculated. The first were the mean bi-hourly movements for each day. The second were the sum of the bi-hourly movements for the day, or the total minimum daily movements of each turtle. The total daily movements were averaged to determine the mean total daily movements and summed to determine the total movements for each turtle for the length of the study period. The mean, standard deviation, and standard error

were calculated and compared for each individual, for males as a group, for females as a group, and for all turtles.

Minimum Overnight Movements. Overnight movements were estimated by establishing the initial location as the last recorded location for each day and the final location as the first recorded location for the next day. These movements were calculated for each turtle. The mean, standard deviation, and standard error were calculated and compared for each individual, for males as a group, for females as a group, and for all turtles for the length of the study period.

HABITAT CHARACTERIZATION

Habitat characterization was conducted in October 1992. Habitat characteristics were recorded on a 10 m x 10 m grid (Figure 8). Permanent transect lines, 10 m apart, were marked with wooden stakes approximately 10 m upslope from the north shore. Each transect was then divided into 10 m sections. Habitat characteristics were recorded from an inflatable raft for each grid point along each transect.

Twelve habitat characteristics were examined based on their perceived importance to western pond turtles (Bury 1970, Holland 1991) (Table VI). These characteristics were measured or estimated, as described below, at each transect and point intersect.

TABLE VI
HABITAT CHARACTERISTICS EVALUATED
AT CARMINE LAKE

a. Categorical variables

Habitat Characteristic	Categories
Type of nearest refugium	1) Undercut bank 2) Rock 3) Submerged tree/snag 4) Emergent vegetation 5) Vegetated log
Type of basking site	1) Dirt 2) Log/snag 3) Emergent vegetation 4) Vegetated log
Aspect of basking site (compass direction of largest surface)	1) N 2) NNE 3) E 4) SE 5) S 6) SSW 7) W 8) N/S
Type of substrate	1) Gravel 2) Mud
Type of vegetative cover	1) Floating macrophytes 2) Emergent macrophytes 3) Submerged macrophytes 4) Floating and emergent macrophytes

b. Continuous variables

Habitat Characteristic	Measurement units	Precision
Distance to shore	m	10 cm
Depth of water	cm	1 cm
Distance to nearest refugium	m	1 m
Distance to nearest basking site	m	1 m
Slope of basking site	in degrees	5°
Estimated surface area of basking site	m ²	10 m ²
Percent vegetative cover	%	5 %

Distance to Shore

Distance from the transect and point intersection (observation point) to the beginning of the transect was measured with a 100-m tape. Distance to shore was then calculated with the following formula:

$$\text{Distance to shore} = \sqrt{(X_p - X_s)^2 + (Y_p - Y_s)^2},$$

where (Figure 8):

X_p = transect number of the observation point x (10 m)

X_s = transect number of the nearest shore x (10 m)

Y_p = point number of the observation point x (10 m)

Y_s = point number of the nearest shore x (10 m)

Depth of Water

Depth of water was measured at each observation point using a 3-m measuring stick with a string tied to one end. When depth exceeded 3 m, the stick was lowered to touch the bottom of the lake, and the submerged stick and string were measured to determine depth.

Type of Nearest Refugium

Nearest refugium was defined as the structure which might provide cover to a turtle. Presumed refugia included: 1) undercut banks, 2) flocculent semi-solid substrate (mud), 3) rock, 4) submerged tree or snag, 5) root mass, 6) brush, 7) emergent vegetation, 8) floating vascular vegetation, 9) algae, and 10) vegetated log. Mud and floating vascular vegetation were not evaluated as refugia because nearly all of Carmine Lake had

a mud bottom and/or was covered with floating vascular vegetation. Consideration of these potential refugia would add little insight into the use of other available refugia.

Distance to Nearest Refugium

Distance to nearest refugium (excluding mud and floating vascular vegetation) was estimated from each observation point to the nearest meter to a distance of 20 m. At distances beyond 20 m, the distance was estimated to the nearest 5 m.

Type of Nearest Emergent Basking Site

Basking sites were considered to be any object upon which a turtle could expose themselves to allow emergent basking. Basking sites included sites where turtles were observed to be basking and potential sites where emergent basking could occur. Objects found to be potential basking sites at the study areas included: 1) dirt, 2) bare log/snag, 3) vegetated log, and 4) emergent vegetation.

Distance to Nearest Basking Site

Distance was estimated to the nearest 5 m from the observation point to the closest margin of the presumed basking site.

Surface Area of Basking Site

The surface area of the nearest presumed basking site to the observation point was estimated based on the dimensions of the potential basking surface. Each dimension was estimated to the nearest 5 cm, therefore the estimated surface area may be $\pm 25 \text{ cm}^2$.

Surface Area of Basking Site

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Aspect of Basking Site

The aspect of the basking site was the major compass direction to which the largest surface faced. If the largest surface of the presumed basking site was flat (i.e., a floating log) the directional axis of the longest dimension was recorded (i.e., east/west).

Slope of Basking Site

Slope of the nearest basking site surface from horizontal was estimated to the nearest 5° .

Type of Substrate

Types of substrate considered included: 1) boulders (rock material $> 1 \text{ m}$ in its largest dimension); 2) cobble (rounded rocks 2-50 cm in the largest dimension); 3) gravel (1 mm - 2 cm); 4) mud; 5) sand; and 6) mixtures of boulders, rock (2-100 cm), cobble, gravel, and sand (less than 1 mm). The only substrates types observed at Carmine Lake were mud and gravel.

Vegetative Cover Type

Plant material that occurred within the surface area of the lake was considered vegetative cover. Two types of cover were observed: 1) floating macrophytes, and 2) a

mixture of floating and emergent macrophytes. Vegetative cover was considered a mixture if neither one of the two cover types was overwhelmingly dominant, approximately a 1:2 ratio.

Percent Vegetative Cover

Percent vegetative cover was considered to be the percentage of the water surface around the observation point which was covered with vegetation. The vegetative cover was estimated within a circular 10 m² ($\approx$ 5.6-m diameter circle) area of open water around the observation point. Cover was visually estimated to the nearest 5 percent.

HABITAT UTILIZATION

Seasonal habitat utilization was examined combining telemetry and habitat characterization, using methods described by White and Garrott (1990). Habitat use was determined with the use of the transect/point grid defined during habitat characterization. A grid was drawn on acetate to match the configuration and scale used in the habitat characterization method. This grid was then superimposed on the aerial photo and locations were obtained from telemetry. The location of each turtle was estimated to be that transect/point intersection closest to the actual, recorded location.

The locations of the turtles were then compared to the habitat characterization data. Each of the twelve habitat characters was separated into classes (Table IV) and the number of locations which occurred within each class was determined. The number of observation points within each class of a given habitat characteristic was then compared

to turtle occurrence within each class of a given habitat characteristic. Turtle occurrence was as frequent as expected when equal to the proportion available for a given habitat variable. Chi-square tests were used to determine whether the pattern of turtle occurrence differed significantly across habitat features.

RESULTS

SAMPLING OBSERVATIONS

Capture Effort

Manual capture effort varied widely over six years (Table VII). From 1987 to 1989, one manual capture interval was attempted during each year, whereas from 1991 to 1993, two to six manual capture intervals were attempted annually. No sampling was conducted in 1990 to reduce risk that turtles could contract URD through contact with field equipment used with a population concurrently studied in Washington. Trapping efforts using mesh traps are not shown. Few turtles were captured in mesh traps, and trapping effort was unrecorded in 1993.

Capture Rate

Average manual capture rate was 12.0 individuals/hr (Table VII). The capture rate for mesh traps in 1992 was 0.02 individuals/hr. The data were not available to calculate capture rates in 1993 because sampling times were not recorded.

OBSERVATIONS OF CAPTURED TURTLES

Post-hatch turtles were captured on 25 different occasions over six years between July 1987 and October 1993. A total of 253 captures were made between 1987 and 1993

(Figure 9). Of these, 183 individuals were captured and marked; the remaining 70 captures consisted of 55 individuals captured more than once (Appendix C).

TABLE VII
MANUAL CAPTURE EFFORT AT CARMINE LAKE, 1987-1993.

Year	Date	Time in water (hr)	Captures	Effort (captures/hr)
1987	30 Jul	1.0	6	6.0
1988	26 Aug	0.5	7	14.0
1989	15 Jun	0.5	9	18.0
1991	21 Jun	2.0	52	26.0
	5 Aug	0.5	7	14.0
1992	27 May	3.8	36	9.5
	02-04 Jun	2.8	14	5.0
	11 Jul	0.5	6	12.0
	4 Aug	1.0	5	5.0
1993	04-06 Jun	2.3	27	11.7
	26 Jun	0.8	9	11.3
Total		15.7	178	11.3

Of 183 individuals captured, 47 (25.6%) were adult males, 46 (25.1%) were adult females, and 67 (36.6%) were subadults. Another 15 (8.2%) turtles captured in October 1993 could not be sexed because of obvious errors in observer classification. The numbers of males ($n = 47$) and females ($n = 46$) captured at Carmine Lake were not significantly different ($\chi^2 = 7.14$, $p = 0.210$). Significantly more adults ($n = 93$) than juveniles ($n = 67$) were captured ($\chi^2 = 16.76$, $0.001 < p < 0.005$).

Fifty-four individuals were captured more than once. Of these, 41 were captured twice, 10 were captured three times, and 3 were captured 4 times. Juveniles were the least often recaptured age or sex group (Appendix C) ($\chi^2 = 18.51$, $p < 0.001$).

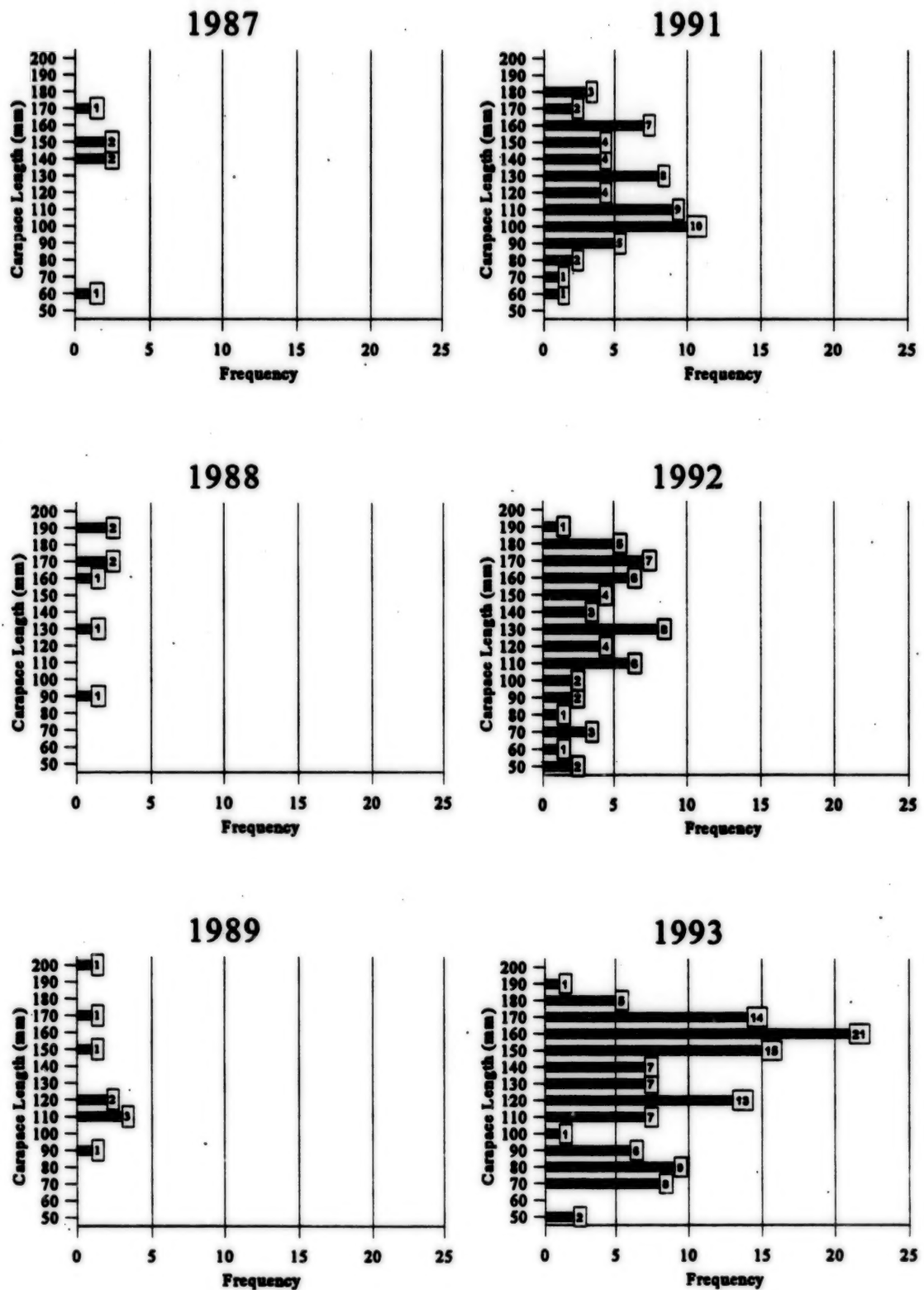


Figure 2. Size frequency of turtles captured within each sampling season, Carmine Lake, 1987-1993.

However, recapture frequency did not differ between adult males and females ($\chi^2 = 0.170$, $p = 0.680$).

POPULATION ESTIMATE

Population estimates of northwestern pond turtles at Carmine Lake were made based on data gathered during three summers (Table VIII). The estimated population size at Carmine Lake ranged between 43-377 turtles. However, low numbers of captures and recaptures in 1992 and low numbers of recaptures overall limit the reliability of the estimates. Mark and recapture efforts from 1986-1990 could not be used for this analysis because of the lack of repeated sampling within each sampling season.

TABLE VIII
POPULATION ESTIMATE, 1991-1993.

Year	Marked in population (r)	# Captured in sample (n)	Marked in sample (m)	Population estimate $\frac{r(n+1)}{(m+1)}$	Standard Error $\sqrt{\frac{r^2(n+1)(n-m)}{(m+1)^2(m+2)}}$
1991	52	7	3	104	32.9
1992	43	1	1	43	0
	44	6	1	154	75.1
	50	5	1	150	70.7
	Mean			113	44.7
1993	23	1	3	81	30.4
	33	4	6	212	68.9
	51	3	4	377	143.3
	Mean			223	80.9

TURTLE SIZE AND GROWTH

Turtles captured between 1987 and 1993 ranged between 38.3 and 194.3 mm CL (Appendix C). Turtles between 110 and 135 mm CL were classified as subadult, even if secondary sexual characteristics were distinct because turtles of this size range were likely unable to reproduce.

The average growth rate for all turtles that were recaptured over the 7-year study period was 13.8 mm CL/yr (SE = 2.01 mm/yr). The average growth rate for adult males and adult females was not significantly different ($\chi^2 = 0.169$, $p = 0.680$), but the growth rate for subadults and juveniles was significantly greater than for adults (Table IX). Juvenile growth rate was also significantly greater than that of subadults (Table IX).

TABLE IX

AVERAGE GROWTH RATES (MM/YR) OF WESTERN POND TURTLES
AT CARMINE LAKE, 1987-1993.

Life Stage	Male		Female		Nonadult	
	Growth rate	SE	Growth rate	SE	Growth rate	SE
Adult	4.59	2.38	4.42	1.11	N/A	
Subadult	10.87	2.39	12.02	4.61	10.62	1.56
Juvenile	N/A		N/A		26.89	6.25

At Carmine Lake, regression analysis showed that turtle growth rate decreases exponentially with increasing size (Figure 10) ($F = 26.93$, $p < 0.001$). Growth was rapid

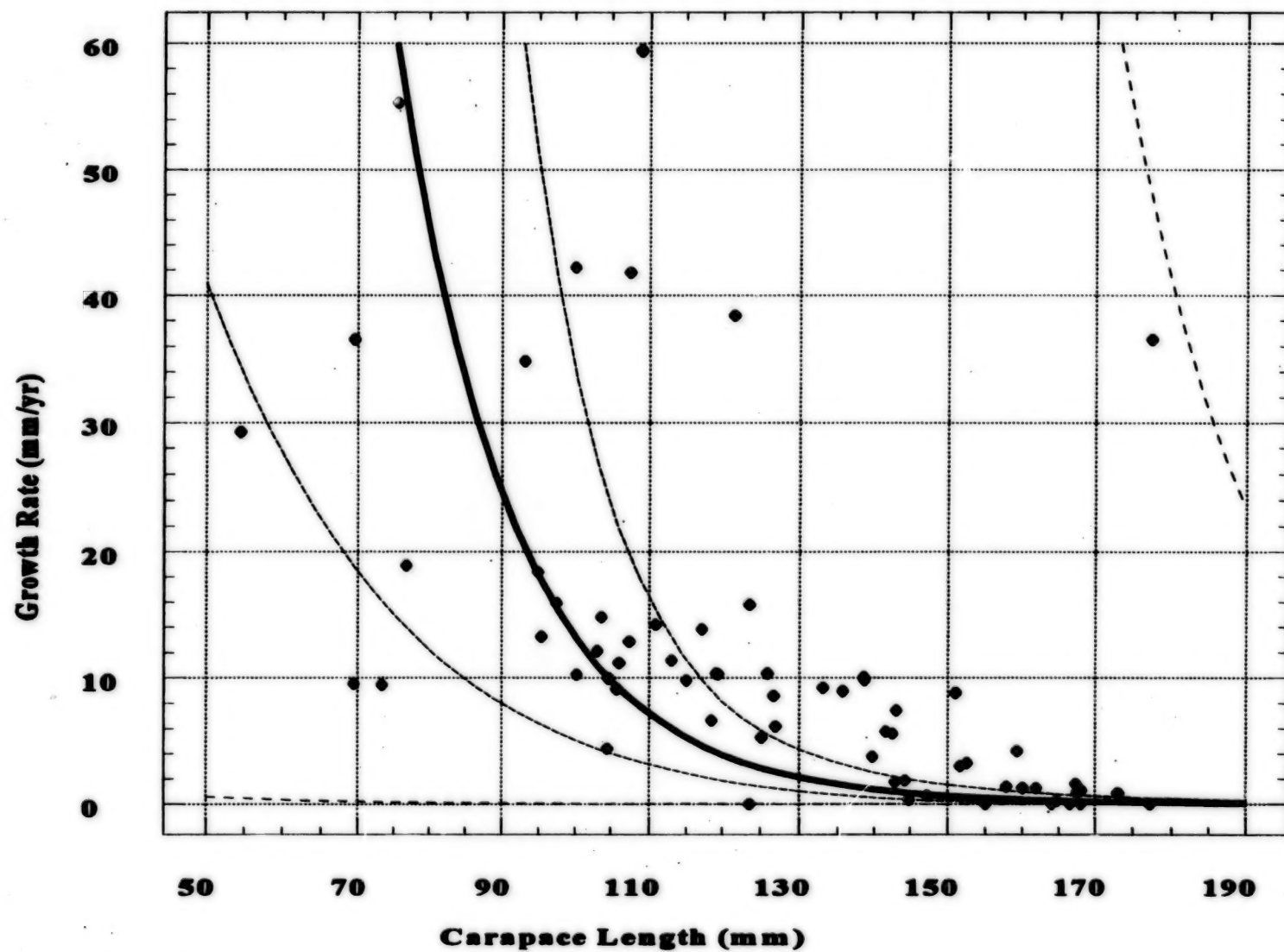


Figure 10. Turtle growth rate at Carmine Lake, OR, 1988 - 1993.

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up to about 110 mm, slowed in the interval 110 - 135 mm, and was reduced to very low levels above after 135 mm.

VISUAL OBSERVATIONS

Turtles were observed while emergent and water basking throughout the day at Carmine Lake (Table IX). Numbers of turtles counted per observation period ranged from 0-92 during 1992. The visuals in 1993 ranged from 0-147. More visual observations were recorded in 1993, but the U.S. Forest Service added two large supplemental basking sites in Carmine Lake in late fall 1992, potentially changing the numbers of visible turtles. The majority of the turtles observed were seen during the 1000 hr observation period during both years (Table X). Significantly more turtles emergent ($\chi^2 = 3344.01$, $p < 0.001$) and water ($\chi^2 = 1664.30$, $p < 0.001$) basked during the 1000 hr observation interval than expected (Figure 11).

TABLE X
NUMBERS OF TURTLES VISUALLY OBSERVED AT
CARMINE LAKE, 1992-1993

	1992	1993
# Observation periods	132	85
Total # of turtle observations	3594	3404
Mean ($\bar{x}$) # of turtles observed/period	27.2	40.0
Standard Deviation (S)	30.2	36.1
Mean for 1000 hr observation period ($\bar{x}_{1000}$)	39.4	58.3
Mean for 1400 hr observation period ($\bar{x}_{1400}$)	15.0	22.2

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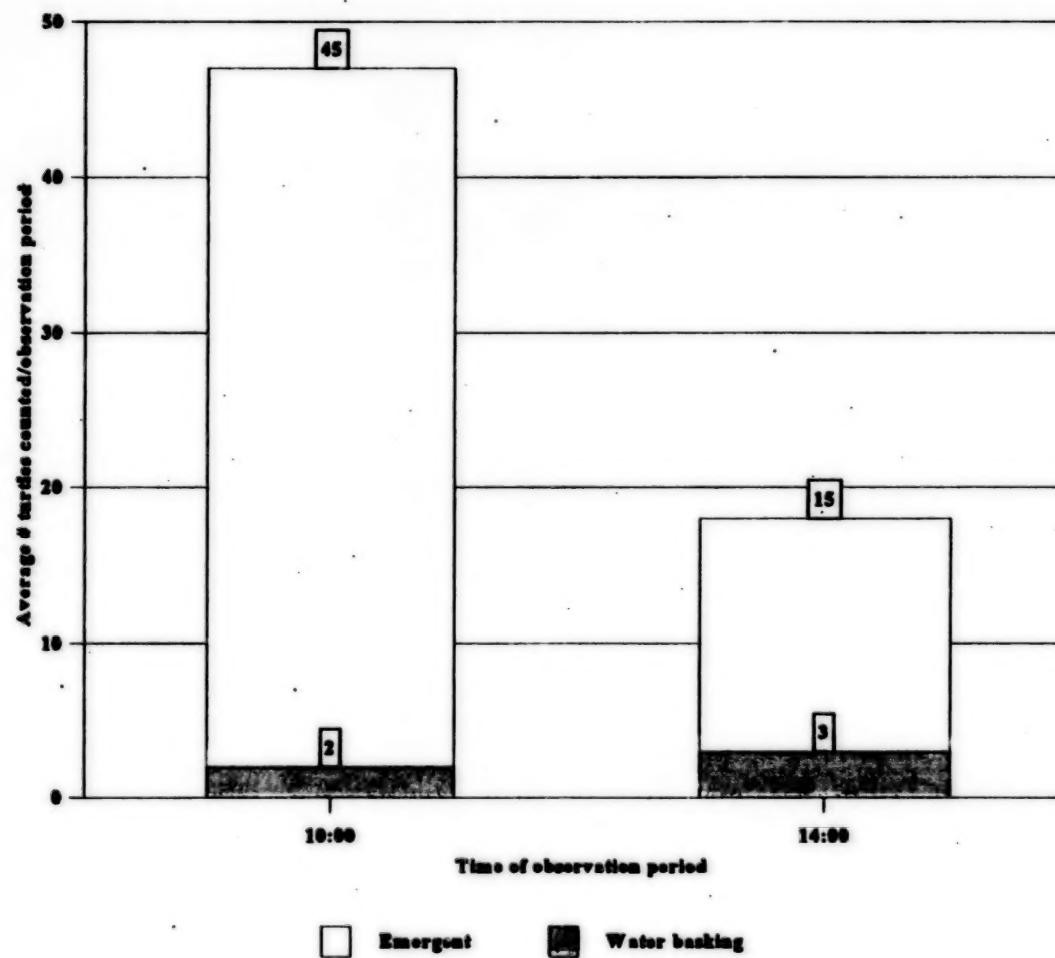


Figure 11. Average number of turtles observed basking at 1000 and 1400 hr observation intervals, Carmine Lake, 1992-1993.

The numbers of turtles seen emergent basking varied with the local weather conditions. More turtles basked before 1000 hr on sunny days when temperatures were between 20-25 °C and wind speed was less than 6 kph (4 mph). Fewer turtles were almost always observed at 1400 hr than were observed at 1000 hr. Fewer turtles basked in the rain, showing significant avoidance ($\chi^2 = 6.11$, $0.025 < p < 0.01$), whereas more turtles preferentially basked during dry weather ($\chi^2 = 37.68$, $p < 0.001$).

The frequency of turtles emergent basking varied with temperature and was normally distributed, with the peak at 20-25 °C (Figure 12). Fewer turtles than expected emergent basked at temperatures < 10 ($\chi^2 = 23.27$, $0.005 < p < 0.001$) and ≥ 25 °C ($\chi^2 = 474.62$, $p < 0.001$), whereas more than expected emergent basked at 10-25 °C ($\chi^2 = 277.04$, $p < 0.001$).

Wind speed affected the number of turtles observed emergent basking (Figure 13). Frequency of emergent basking declined when wind velocity exceeded 5 kph [3.1 mph]. Turtles basked significantly more than expected when there was no wind ($\chi^2 = 27,700$, $p < 0.001$) and basked significantly less than expected when there was a wind of any speed ($\chi^2 = 1732.98$, $p < 0.001$).

Rain affected the frequency of emergent basking ($\chi^2 = 43.80$, $p < 0.001$) and water basking ($\chi^2 = 6.22$, $0.025 < p < 0.01$) (Figure 14). Fewer turtles than expected emergent basked ($\chi^2 = 37.68$, $p < 0.001$) and water basked ($\chi^2 = 5.35$, $0.025 < p < 0.01$) in rain. Dry conditions resulted in higher frequency of emergent basking ($\chi^2 = 6.11$, $0.025 < p < 0.01$) but no significant difference in water basking ($\chi^2 = 0.87$, $0.9 < p < 0.5$).

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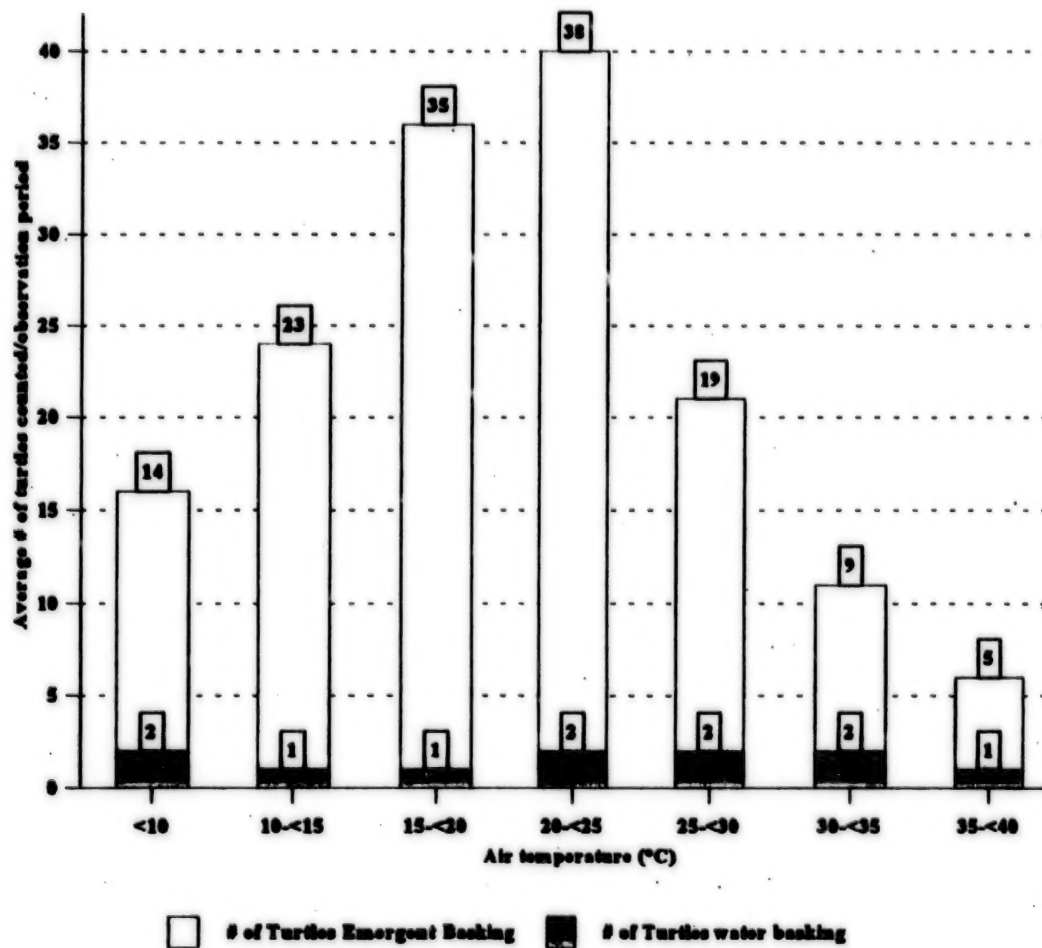


Figure 12. Average number of turtles observed basking at recorded air temperatures, Carmine Lake, Oregon, 1992-1993.

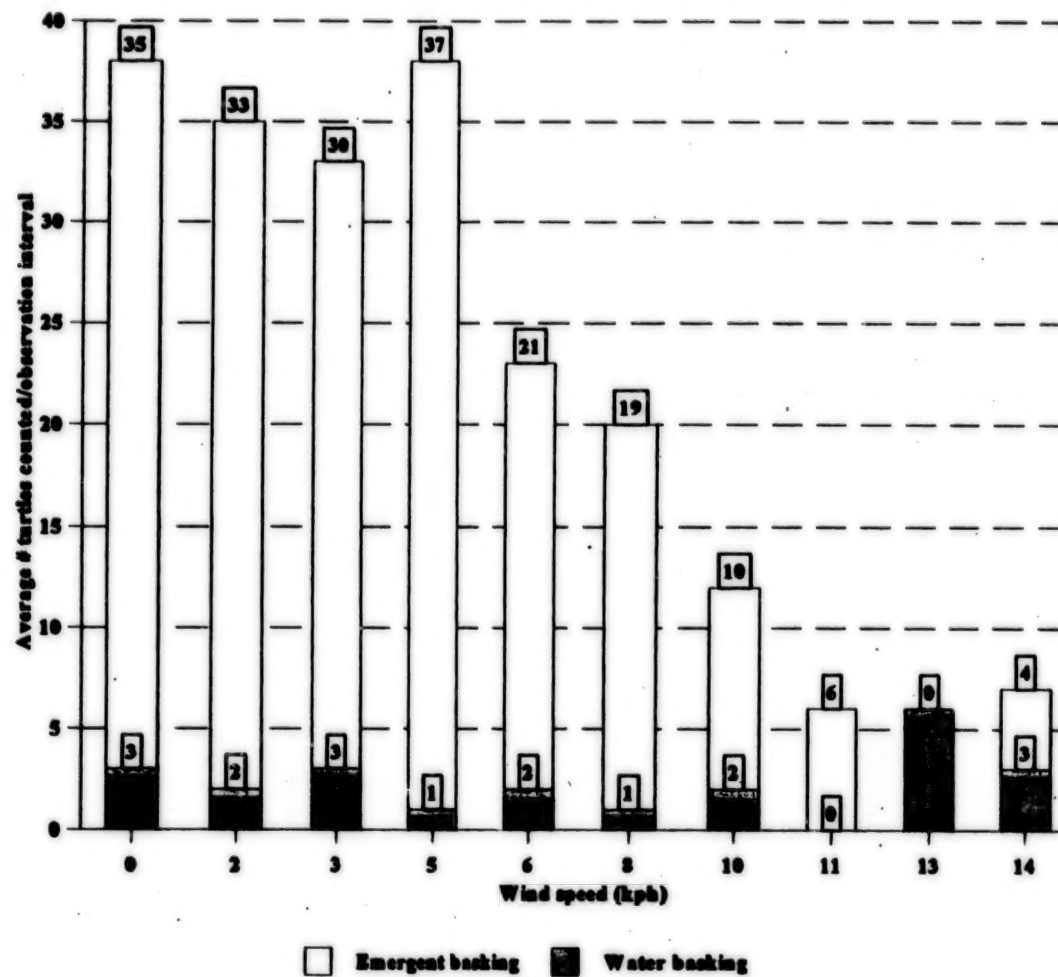


Figure 13. Average number of turtles observed basking at recorded wind speeds, Carmine Lake, OR, 1992 -1993.

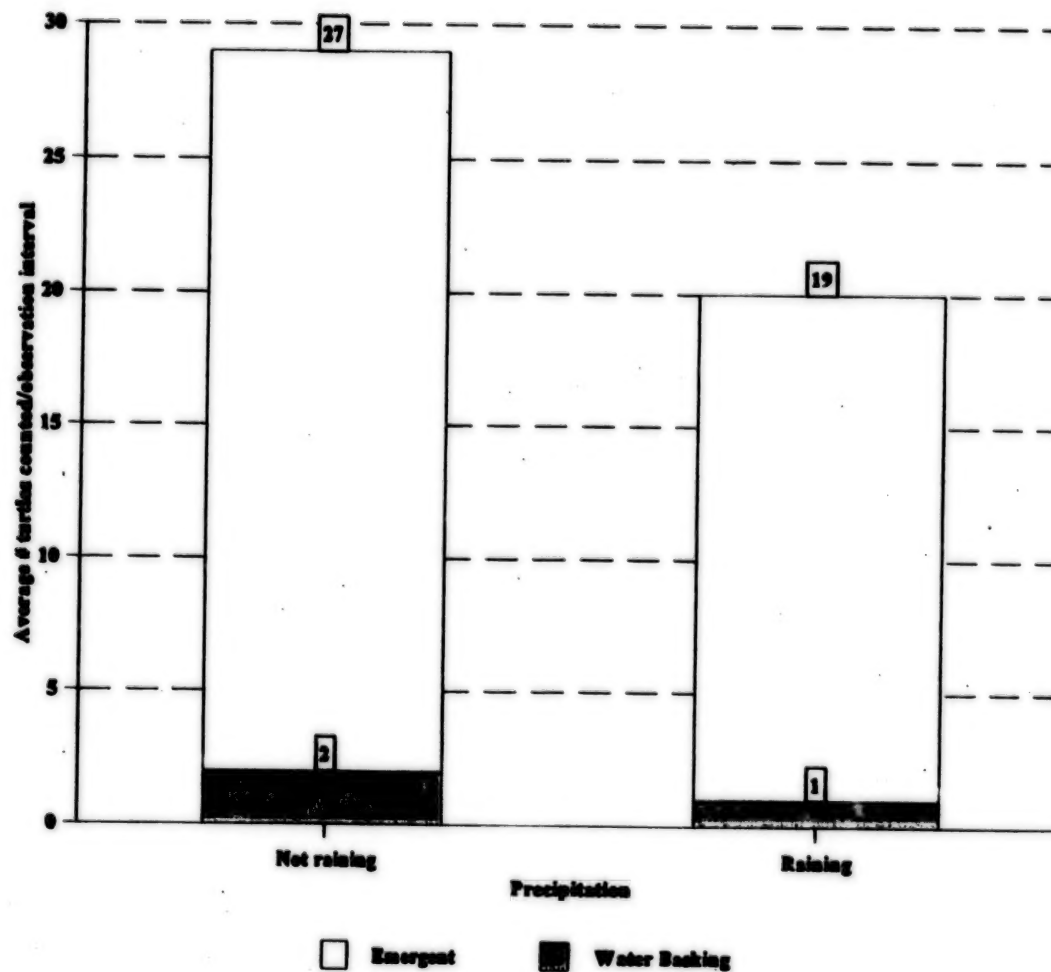


Figure 14. Average number of turtles observed basking with respect to precipitation, Carmine Lake, 1992-1993.

Water basking varied little with time, air temperature, or rain (Figures 12, 13, and 15). Water basking increased slightly as wind speed increased (Figure 14). Fewer than expected turtles water basked when wind speeds were 1-5 kph [1-4 mph]. Wind speed $\geq$ 6 kph [4 mph] had no significant effect on the actual frequency of compared to expected frequency of water basking turtles even though the frequency of basking appeared to increase at 13-14 kph [8-9 mph].

TELEMETRY

Fourteen adult turtles (>130 mm CL, Table XI) were tracked between 4 June and 7 October 1992. A total of 3,434 turtle locations were recorded during this interval.

Twelve turtles, six males and six females, were equipped with transmitters and released on 4 June 1992. Two additional turtles, one male (#7270) and one female (#7271), were equipped with transmitters and released on 11 July 1992, to replace three turtles that left Carmine Lake within the first week of release. The signals for these three emigrants, all males, could not be detected until all were located in nearby Castor Lake in July.

Another male (#7200) was found dead in Carmine Lake on 5 July 1992. No apparent trauma was found, and a necropsy eliminated the possibilities of upper respiratory disease or angling-related injury as causes of death (Mark Burgess, D.V.M., pers. comm.). The transmitter and half the antenna were missing. Death may have been related to the telemetry equipment, but this possibility remains unconfirmed. Two of the six females equipped with transmitters were gravid (Table XI), but neither of these individuals were observed nesting, and no viable or excavated nests were located.

TABLE XI
TURTLES EQUIPPED WITH TRANSMITTERS
AT CARMINE LAKE, OR, 1992-1993

Turtle #	Transmitter frequency (MHz)	Transmitter color (anterior to posterior)	Size (mm)	Sex	Gravid
1789	151.236	green/blue	148.8	F	N
7247	150.330	blue/yellow	150.3	F	N
7271	151.695	blue with red dot	150.9	F	N
5524	150.838	blue/red	153.0	F	N
1786	151.363	green with red dot	166.5	F	Y
7246	150.089	green	167.0	F	Y
7201	150.170	blue/green	175.9	F	N
5522	151.490	yellow with green dot	160.6	M	
7249	150.369	yellow/blue/ red	164.6	M	
7200	151.571	red with green dot	169.2	M	
7270	150.636	red/blue	174.5	M	
7205	150.249	green/yellow	175.4	M	
7203	150.407	green/red	177.2	M	
7202	151.104	blue	179.5	M	

Aquatic Home Range

Relatively discreet home ranges were evident in plotted locations for each turtle (Appendix D). Some turtles showed much more fidelity to one particular location than others. Home ranges appeared to be centered around known basking sites. Home ranges did not display an obvious sex-specific pattern.

Turtles used approximately 1.5 ha (75%) of the surface area of lake. Home ranges, within this area, averaged 6,600 m² (Table XII). Home range area was not significantly different between males or females ($F = 0.172$, $p = 0.693$).

TABLE XII
HOME RANGE AREAS OF TELEMETERED
TURTLES AT CARMINE LAKE, 1992

Turtle	Sex	Home Range area (m²)	Number of points
1786	F	5,800	309
1789	F	7,600	293
5524	F	3,900	265
7201	F	8,500	285
7246	F	6,800	330
7247	F	7,400	278
7271	F	4,900	159
5522	M	8,000	328
7200	M	6,600	125
7202	M	7,300	317
7270	M	5,300	149
All		12,000	2,838

Overnight Movements

Overnight (2000-0800 hr) turtle movements varied from 0-116 m. The mean overnight distance moved was 39.3 m ($n = 54$, $SE = 2.49$) (Table XIII). Maximum and average overnight distances moved were unaffected by sex of the adult turtles in this study ($U_{(2),4,7} = 23$, $0.02 > p > 0.01$; $U_{(2),4,7} = 17$, $p > 0.20$) or by whether females were gravid or not ($U_{(2),2,5} = 4.5$, $p > 0.20$; $U_{(2),2,5} = 3$, $p > 0.20$).

Movements over the study period

During the study period, turtles moved an average of 149.8 m/day (range = 74-192 m/day, $SE = 12$ m/day [12.5 m/hr, $SE = 0.93$ m/hr]) between 0800 and 2000 hrs (Table XIII).

TABLE XIII
MEAN DISTANCES MOVED BY TELEMETERED TURTLES

Turtle #	Sex	Mean distance moved (m)		
		in a 2-hour interval	in one day	overnight
1786	F	20.3	179.2	35.2
1789	F	28.6	74.6	41.9
5524	F	11.6	182.7	28.3
7201	F	28.3	164.1	47.8
7246	F	25.5	128.1	39.1
7247	F	25.7	127.7	40.1
7271	F	21.6	171.3	35.9
5522	M	23.4	147.0	44.2
7200	M	27.7	185.0	58.3
7202	M	27.9	192.1	31.9
7270	M	19.2	112.6	36.3
7203	M	Emigrated to Castor Lake		
7205	M	Emigrated to Castor Lake		
7249	M	Emigrated to Castor Lake		
Mean		23.6	149.8	39.3

HABITAT UTILIZATION

Twelve habitat characteristics were examined (Table VI). Turtles exhibited preference or avoidance of elements of 11 of the habitat characteristics examined. Turtle occurrence was proportional to the variation in only one habitat characteristic, substrate type (mud and gravel). Among the remaining 11 characteristics, the proportion of turtles using a given variable was significantly higher or lower than the proportion of that habitat variable available in Carmine Lake.

Distance to Shore

The distance of each reference point from the nearest shore varied from 0-51 m. Most points (30%, $n = 36$) were 10-20 m from the nearest shore. Most turtles (34 %, $n = 1076$) also occurred 10-20 m from shore ($\chi^2 = 14.25$, $0.025 > p > 0.01$), however turtles used sites 50-60 m from the nearest shore more than expected ($\chi^2 = 282.58$, $p < 0.001$). Turtles used sites < 10 m from the nearest shore significantly less than expected ($\chi^2 = 211.60$, $p < 0.001$) (Figure 15).

Depth of Water

The depth of water in Carmine Lake varies from 0-2.50 m. The average depth of the lake is 1.17 m ($n = 135$, $SE = 0.05$); the median is 1.30 m. Most of the lake is between 1.0 and 1.75 m (52% of the reference points, $n = 72$). The adult turtles telemetered used water that was 0.50 -0.75 ($\chi^2 = 67.15$, $p < 0.001$), 1.75-2.00 ($\chi^2 = 88.13$, $p < 0.001$), and 2.25-2.50 m ($\chi^2 = 48.28$, $p < 0.001$) deep more than expected, and water < 0.25 m deep ($\chi^2 = 153.57$, $p < 0.001$) less than expected (Figure 16). This pattern would probably be different for juvenile turtles which would be more likely to use water < 0.25 m deep (Holland 1991).

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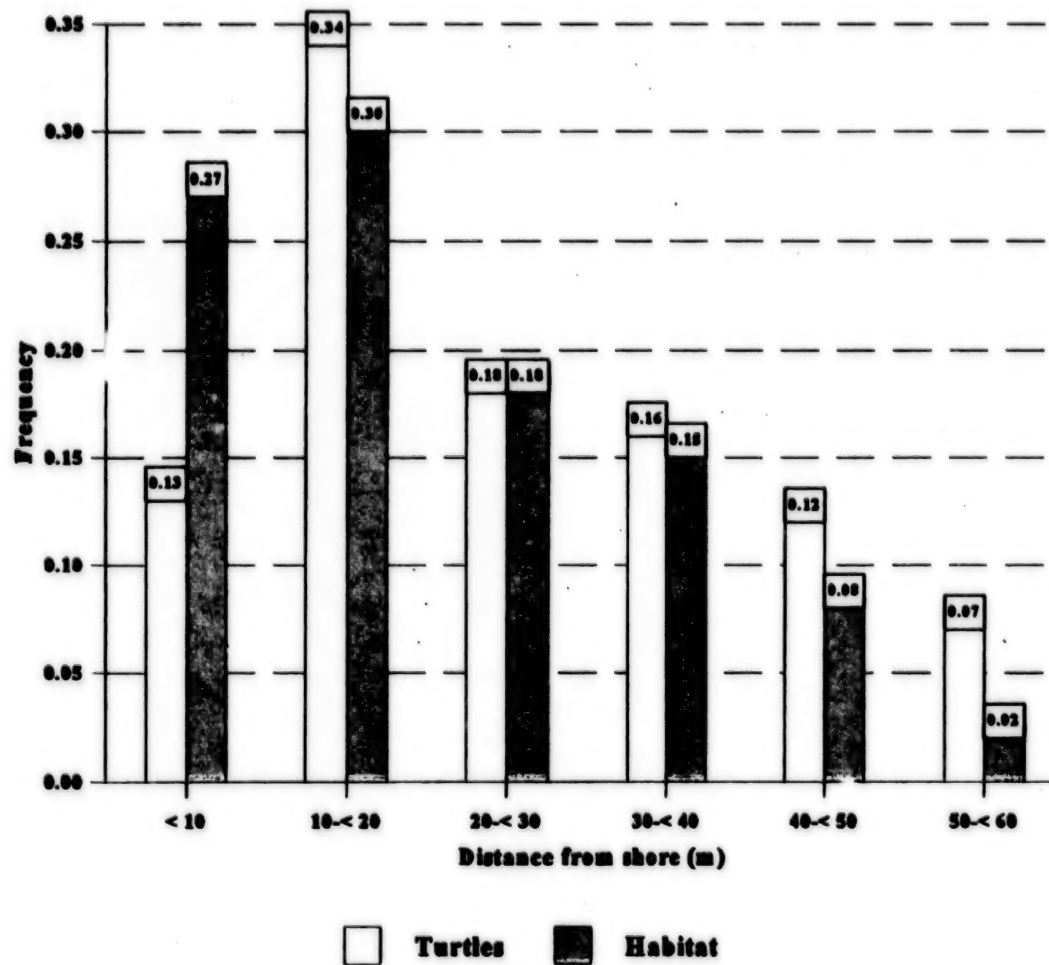


Figure 15. Frequency of turtle occurrence and distances from shore within Carmine Lake.

97

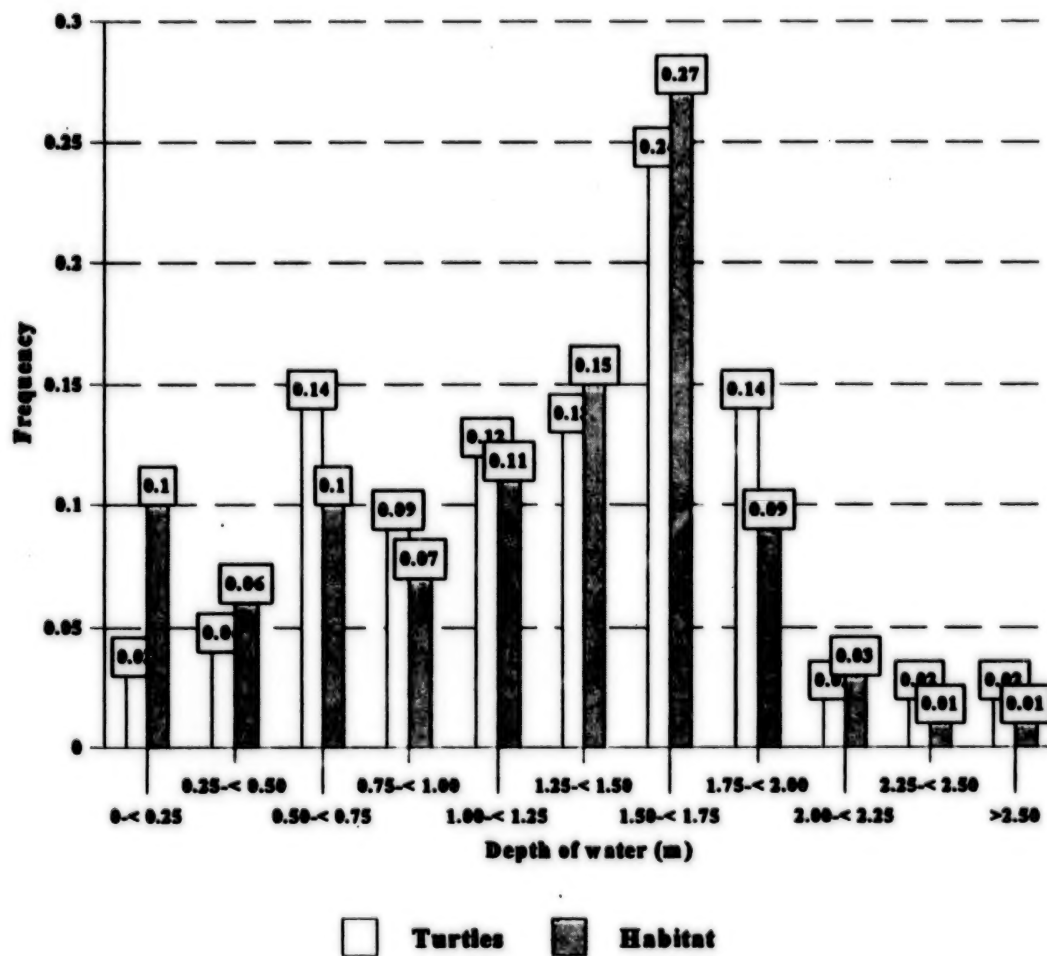


Figure 16. Frequency of turtle occurrence and water depths at Carmine Lake.

98

Type of Nearest Refuge

Four types of refuge were observed and compared at the 135 reference points in Carmine Lake: undercut banks (6%, $n = 8$), submerged trees and snags (63%, $n = 85$), and vegetated logs (31%, $n = 42$) (Figure 17). Turtles used vegetated logs more frequently than expected ($\chi^2 = 50.85$, $p < 0.001$). Submerged trees and snags were used less than expected ($\chi^2 = 21.01$, $p < 0.001$) (Figure 17).

Distance to Nearest Refuge

Distances between the reference points and the nearest refuge varied between 0 - 55 m. Most sites were within 10 m of the nearest refuge (58%, $n = 78$). However, turtles used these sites less than expected ($\chi^2 = 18.28$, $p < 0.025$) (Figure 19). They used sites 20-30 m from the nearest refuge more than expected ($\chi^2 = 138.91$, $p < 0.001$) (Figure 18).

Type of Basking Structure

Five types of presumed basking structures were observed in Carmine Lake: dirt, boulders, emergent vegetation, bare logs or snags, and vegetated logs. The most prevalent type of basking structures were bare logs and snags (51%, $n = 69$), followed by vegetated logs (35%, $n = 47$), boulders (8 %, $n = 11$), emergent vegetation (5%, $n = 7$), and dirt (1%, $n = 1$). Turtles used bare logs and snags significantly more and vegetated logs and boulders significantly less than expected (Figure 19).

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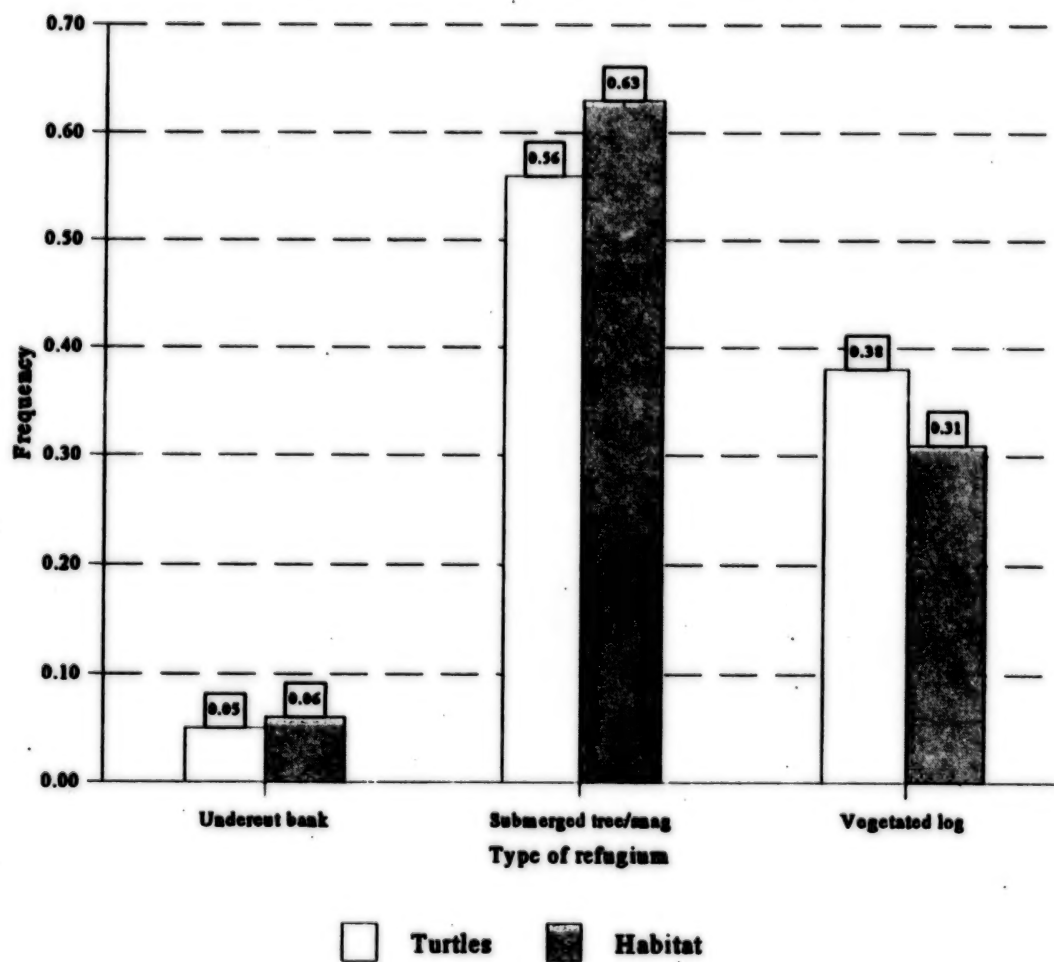


Figure 17. Frequency of turtle occurrence and type of nearest presumed refugium within Carmine Lake.

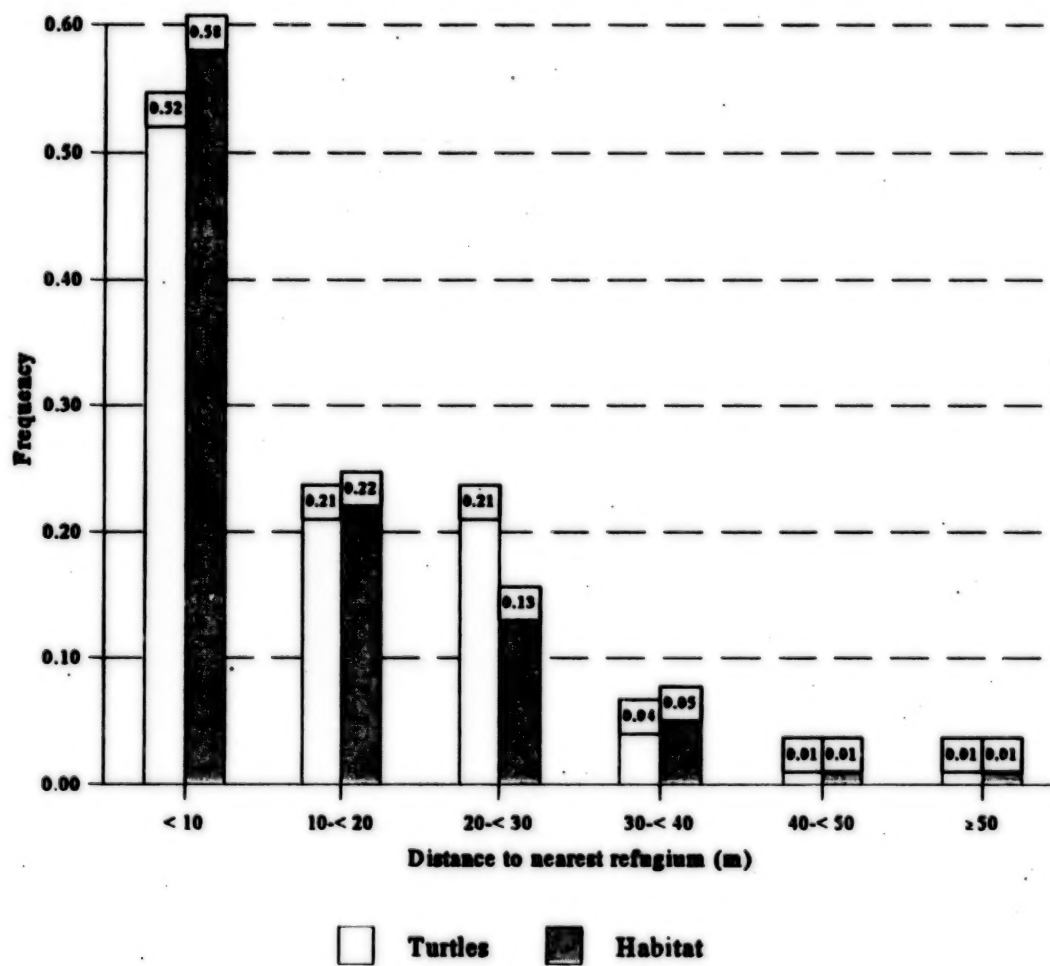


Figure 18. Frequency of turtle occurrence and distance to nearest presumed refugium within Carmine Lake.

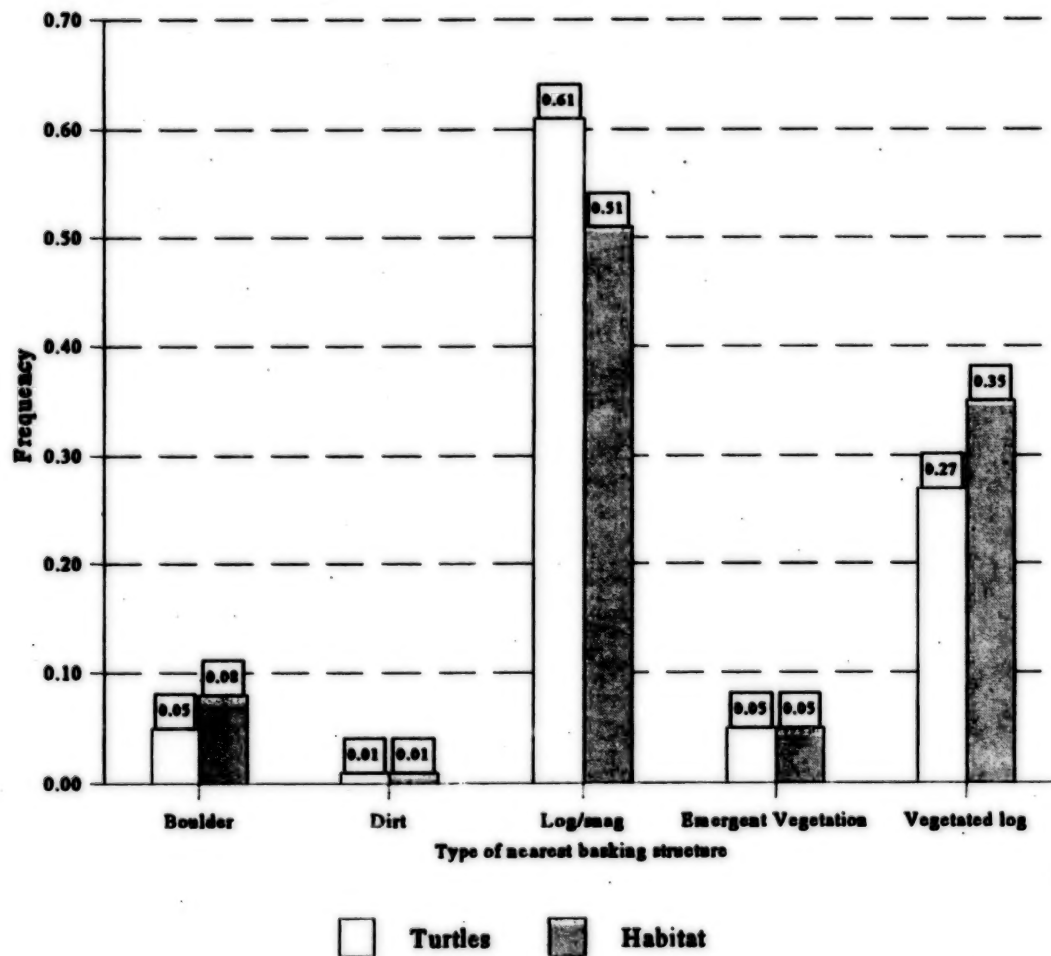


Figure 19. Frequency of turtle occurrence and type of nearest presumed basking structure within Carmine Lake.

Distance to Nearest Basking Structure

Distances between reference sites and the nearest basking structures ranged between 0-60 m. Turtles used sites 20-30 m from basking structures more than expected ($\chi^2 = 42.66$, $p < 0.001$) (Figure 20). Sites 10-20 m from basking structures were used less often than expected ($\chi^2 = 11.52$, $p = 0.025$) (Figure 20).

Basking Structure Slope

Most available basking sites (60%, $n = 81$) had a slope of $< 10^\circ$. However, turtles occurred near basking structures that sloped 20-30° significantly more often than expected ($\chi^2 = 51.84$, $p < 0.001$). Turtles occurred significantly less than expected near basking structures slopes higher or lower than this mid-range (Figure 21).

Basking Structure Aspect

Although most basking structures (40%, $n = 1263$) had no aspect, turtles used structures with southerly ($\chi^2 = 121.42$, $p < 0.001$) and northeasterly aspects ($\chi^2 = 49.69$, $p < 0.001$) (Figure 22). They used sites near structures with a westerly ($\chi^2 = 28.00$, $p < 0.001$) aspect and those that had no aspect ($\chi^2 = 17.39$, $0.001 < p < 0.005$) less frequently than expected.

Surface Area of the Nearest Basking

Basking structures at Carmine Lake varied in area from 0.25-8 m² ($\bar{x} = 3.10$, $SE = 0.20$). Turtles used sites near basking structures with a surface area between

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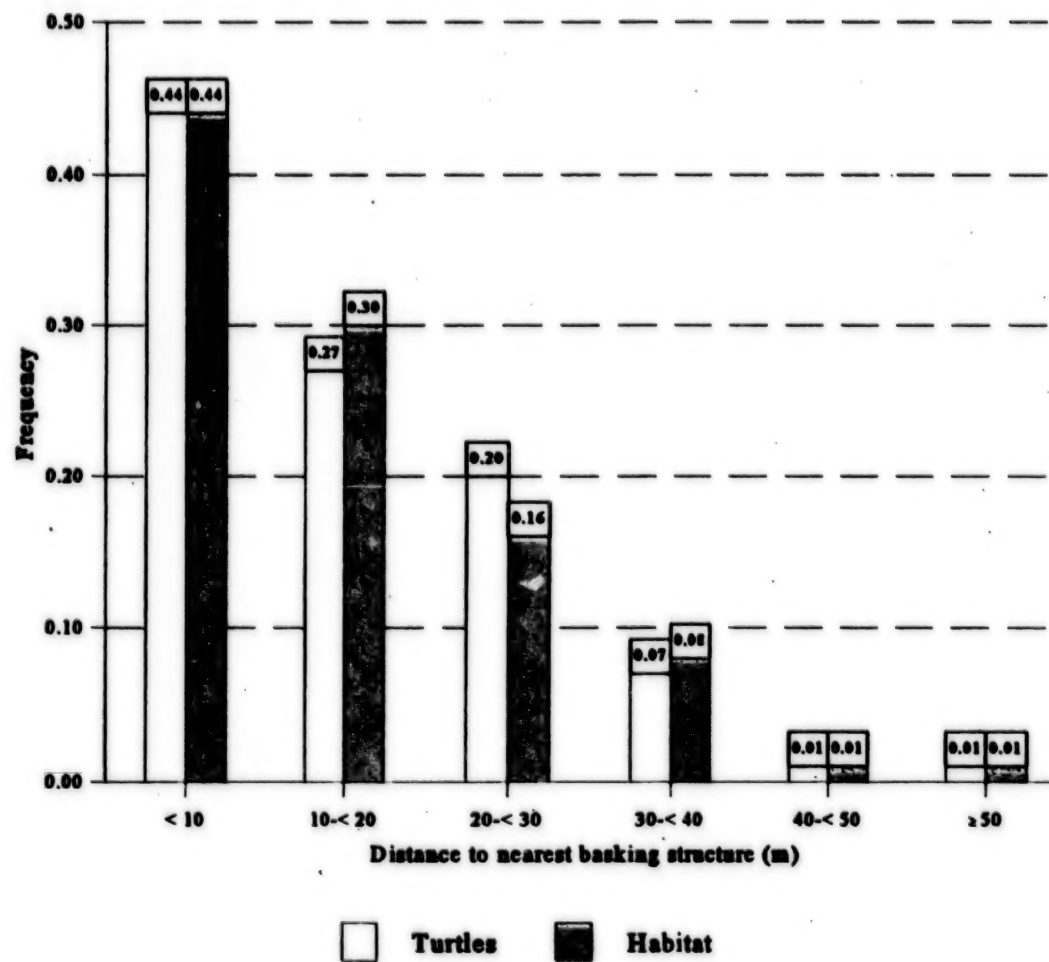


Figure 20. Frequency of turtle occurrence and distance to nearest presumed basking structures within Carmine Lake.

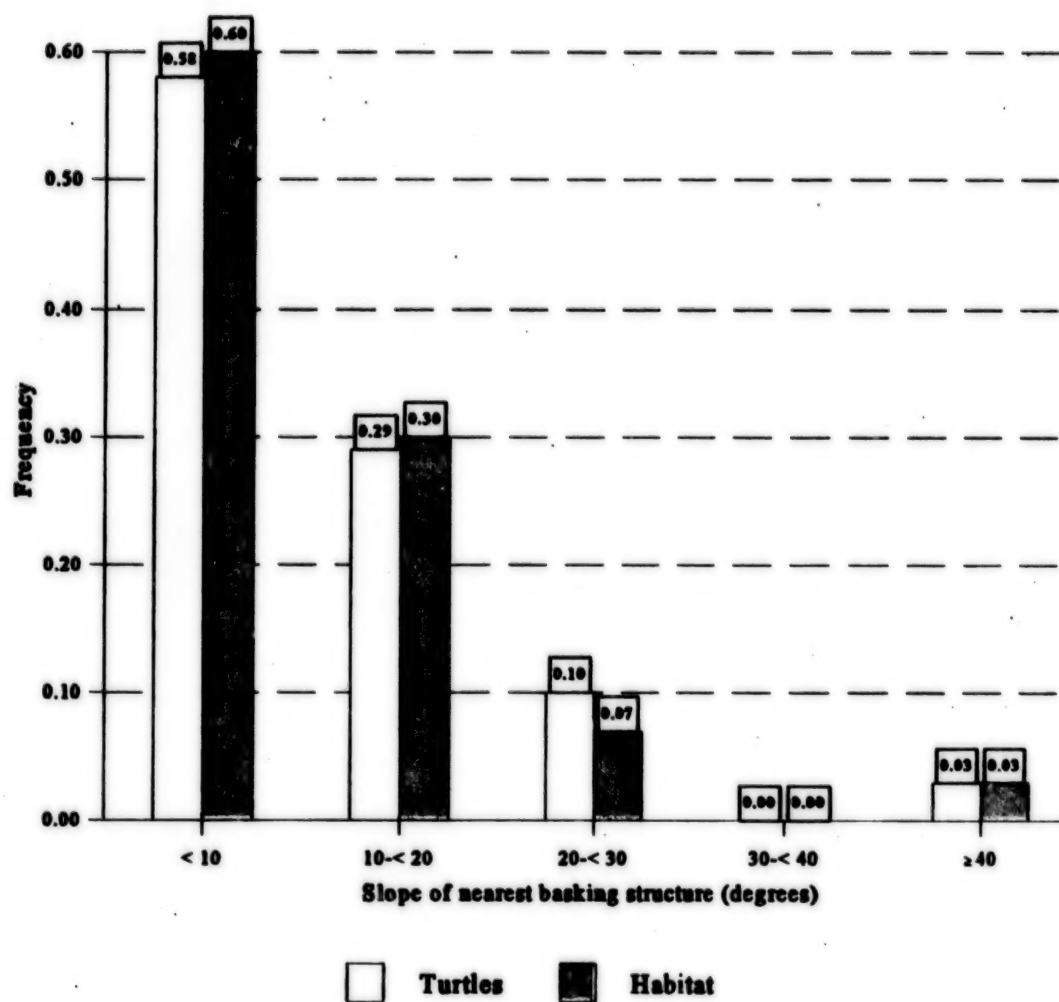


Figure 21. Frequency of turtle occurrence and slope of nearest presumed basking structure, Carmine Lake.

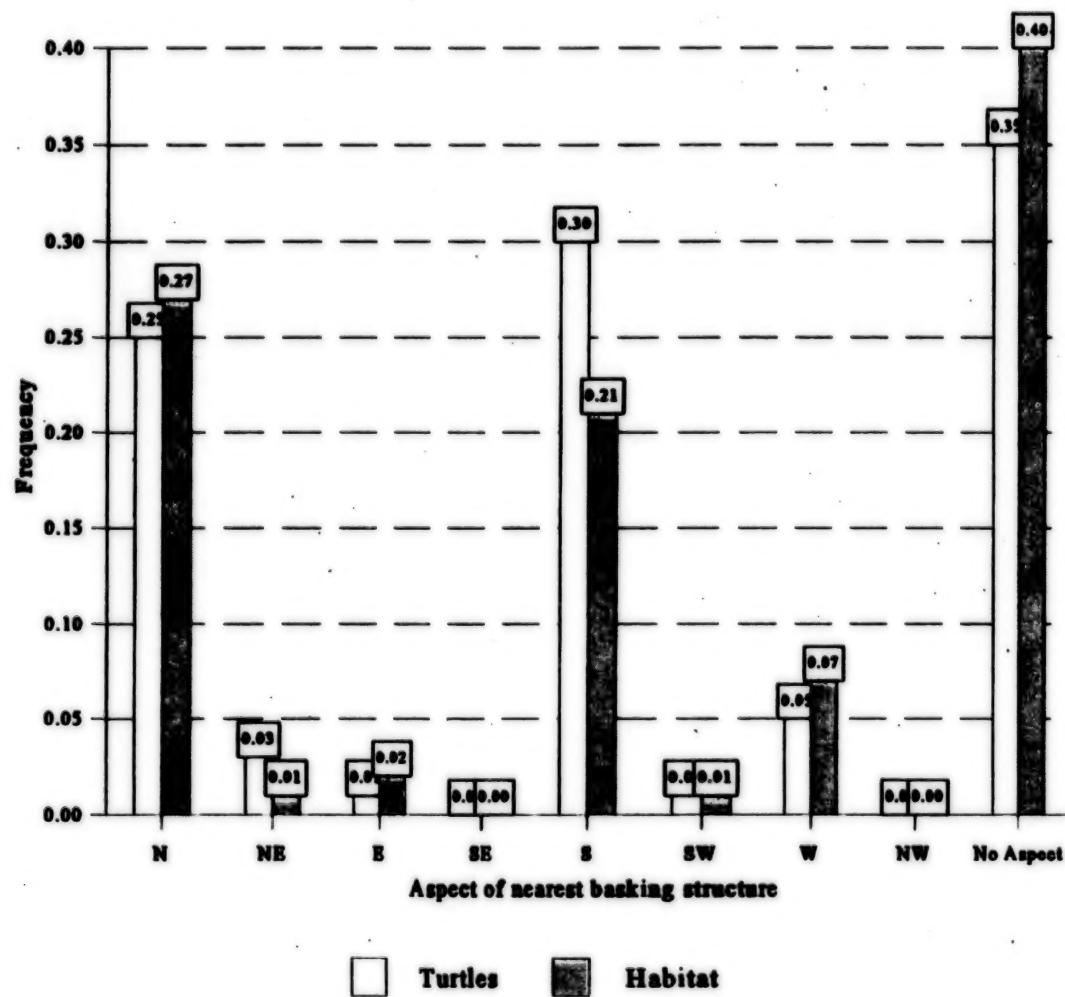


Figure 22. Frequency of turtle occurrence and aspect of nearest basking structure within Carmine Lake.

4-< 5 m² ($\chi^2 = 18.82$, $0.05 < p < 0.025$), 5-< 6 m² ($\chi^2 = 106.97$, $p < 0.001$) and 7-< 8 m² ($\chi^2 = 85.06$, $p < 0.001$) more frequently than expected. Turtles used sites near basking structures between 3-<4 m² ($\chi^2 = 29.38$, $p < 0.001$), 6-<7 m² ($\chi^2 = 29.71$, $p < 0.001$), and >8 m² ($\chi^2 = 62.87$, $p < 0.001$) less often than expected (Figure 23).

Vegetative Cover Type

Of the five categories of vegetative cover types that were observed at Carmine Lake (Table VIb), the prevalent cover type was floating vegetation (93%, $n = 125$). However, turtles used the one site with a mixture of floating and submerged rooted vegetation (1%, $n = 1$) ($\chi^2 = 21.85$, $p < 0.001$) significantly more than expected. This use was attributable primarily to turtle 5524 which accounted for about half of all occurrences at this site. Turtles used sites with emergent vegetation ($\chi^2 = 21.23$, $p < 0.001$; 3%, $n = 4$) and a combination of floating and emergent vegetation ($\chi^2 = 41.84$, $p < 0.001$; 3%, $n = 4$) significantly less than expected (Figure 24). Only four of the eleven tracked turtles used emergent vegetation, and the frequency at which these turtles occurred in this habitat type was not significantly different than expected (Appendix E). All turtles either used a combination of emergent a floating less than expected or did not use the habitat type significantly more or less than expected.

Vegetative Cover

Vegetative cover varied from 0 to 100% ($\bar{x} = 62\%$, $SE = 2.74$) (Figure 25). Turtles used sites characterized by $\leq 20\%$ vegetative cover ($\chi^2 = 66.52$, $p < 0.001$) less than

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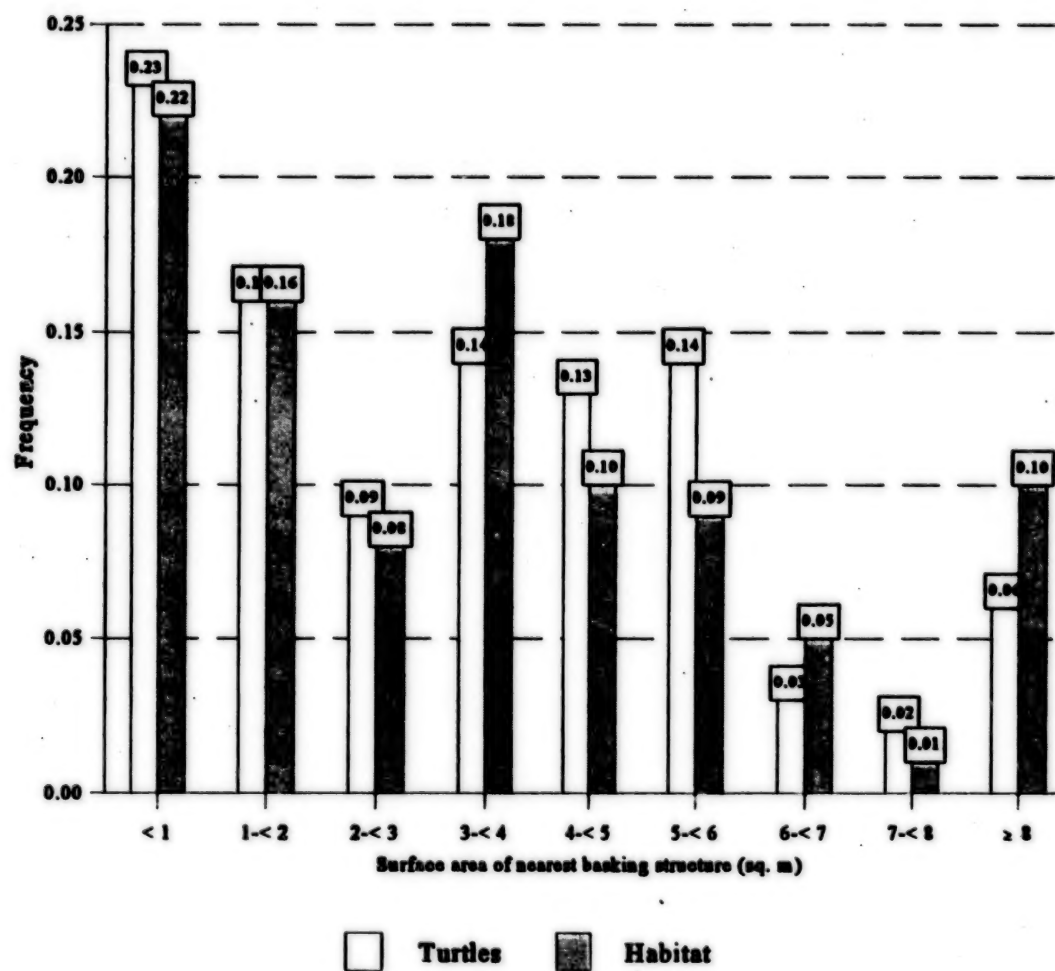


Figure 23. Frequency of turtle occurrence and surface area of basking structure within Carmine Lake.

108

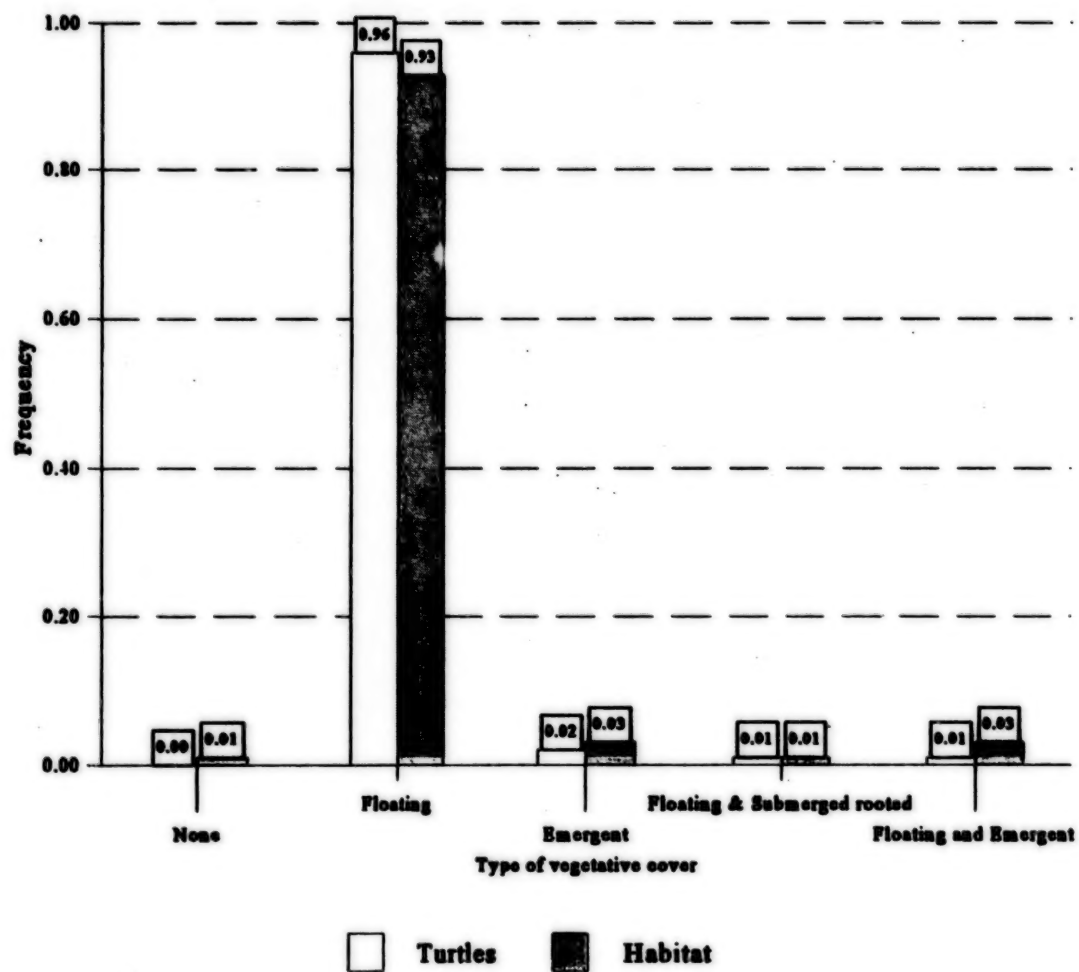


Figure 24. Frequency of turtle occurrence and type of vegetative cover within Carmine Lake.

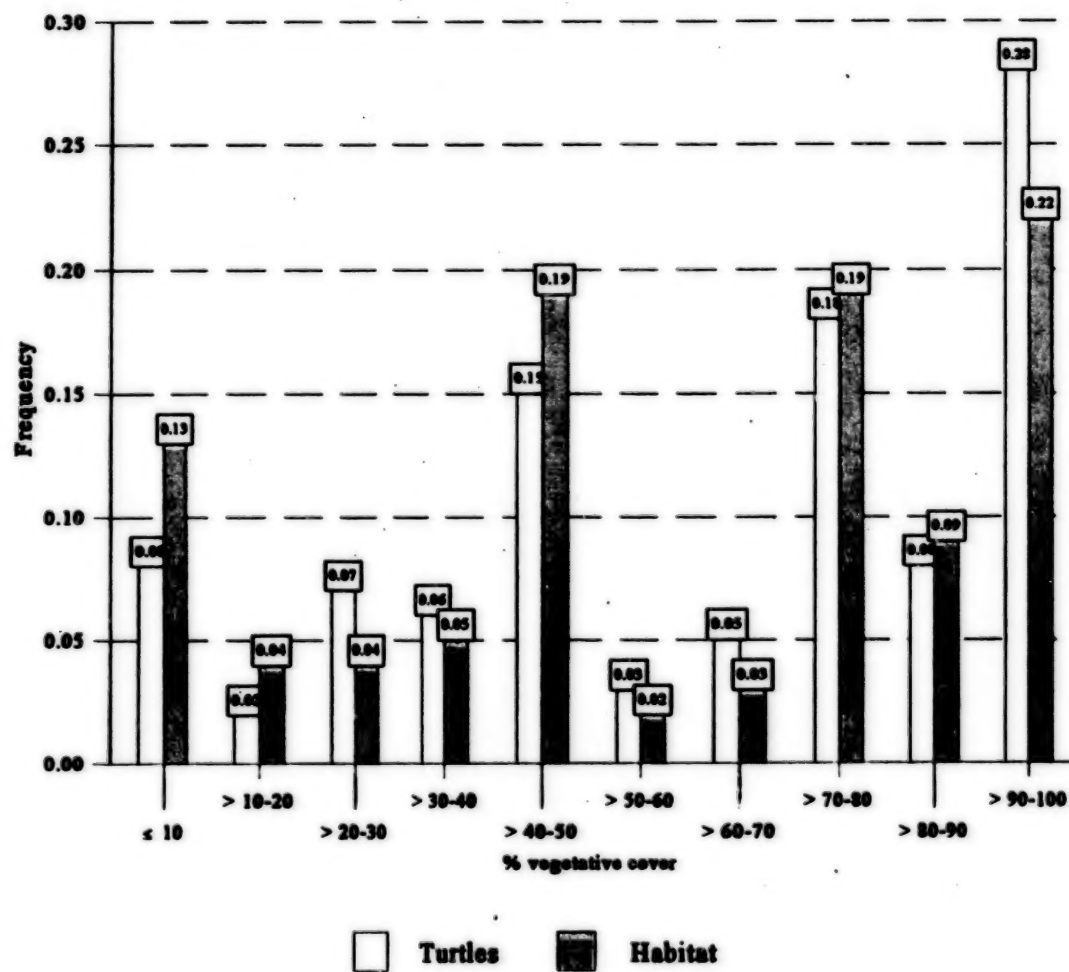


Figure 25. Frequency of turtle occurrence and percentage of vegetative cover within Carmine Lake.

expected. They used sites with > 20-30%, >60-70%, and > 90% vegetative cover more than expected ($\chi^2 = 41.85$, $p < 0.001$; $\chi^2 = 56.07$, $p < 0.001$; $\chi^2 = 39.85$, $p < 0.001$) (Figure 25). Use of sites with these amounts of vegetative cover was primarily contributed by turtles 1786; 5522 and 5524; and 5524, respectively (Appendix E).

DISCUSSION

SAMPLING OBSERVATIONS

Capture Effort and Rate

The most efficient method of capture of northwestern pond turtles at Carmine Lake was manual capture. The most successful attempts were manual captures made over 1-2 days early in the season. Mesh traps caught very few animals, and were bulky and conspicuous, even when disguised with vegetation. Given that the capture success declined rapidly after the first attempts and relatively few turtles were ever recaptured (only 54 [30%] of the 183 individuals at Carmine Lake were captured more than one time in six years and eleven capture intervals), it is likely that turtles become wary after initial capture. Moreover, food resources in Carmine Lake (i.e., dragonfly larvae, aquatic snails, and other invertebrates) may be so abundant that turtles are not attracted to bait in the traps.

CAPTURED TURTLES

Population structure

The distribution of male and female turtles at Carmine Lake was nearly even. However, significantly more adults than juveniles were captured over the six-year study period. This is likely a natural phenomenon because adults captured represent the

cumulative total of more annual cohorts than all juveniles combined. Moreover, little evidence exists of unusual predation on juveniles at Carmine Lake. No exotic predators occur in the lake and suitable juvenile microhabitat is available (i.e., shallow water habitat < 25 cm in depth with emergent vegetation). In addition, food resources appear abundant. It is also possible that the lower proportion of captured juveniles reflects an adult sampling bias. Although this possibility is unlikely, no satisfactory method was available to test this hypothesis.

POPULATION ESTIMATE

Population estimates ranged from 43 to 377 turtles (SE = 0-143.3). This wide variation and error is likely a reflection of the sampling methods used. Success in capturing turtles may be dependent on a variety of factors, including insolation, wind velocity, temperature, previous disturbance, proficiency of the captor, and other unknown elements. Since it is unlikely that these factors would remain constant during the sampling periods, high variability was anticipated. In addition, marked turtles from Carmine Lake were found in Alligator Lake in 1995, three telemetered turtles emigrated from Carmine Lake to nearby Castor Pond, and one telemetered turtle was found dead during the study period. Death, emigration, and immigration may also contribute to the variation in population estimates (Begon 1979).

Improved population estimates at Carmine Lake would depend on multiple sampling intervals during each active season. These sampling periods would have to be of short duration and separated by several weeks without substantial human disturbance.

Sampling should be completed before mid-July because the high productivity of the lake leads to algal blooms and low in-water visibility by late summer. Due to the numerous logs, vegetation, and size of the lake, the entire lake should be systematically sampled, perhaps following the established grid system, in one interval by one captor.

Another possible sampling method that has not been attempted at Carmine Lake is basking site traps. Large numbers of turtles bask when conditions are favorable (see Visual Observations discussion), and the use of basking traps has the potential to provide significant additional data, particularly if combined with the manual capture approach.

TURTLE SIZE AND GROWTH

Recapture of 54 turtles provided growth and growth rate data. Growth rates compared to size approximated a negative log curve (Figure 11). The relative growth rates corresponded closely with size classes considered by Holland (1991) to be juvenile (<110 mm), nonreproductive adults (110 - <135 mm), and reproductive adults (>135 mm) (Table XIV).

TABLE XIV
GROWTH RATE
INTERVALS AND OBSERVED LIFE
STAGES OF WESTERN POND TURTLES

Size	Life Stage	Growth rate interval
<110 mm	Juvenile	Period of rapid growth
110 - 135 mm	Subadult	Moderate growth
>135 mm	Adult	Very little growth

VISUAL OBSERVATIONS

Visual observations represent the number of turtles seen emergent or water basking. The maximum number of turtles seen basking ($n = 147$) represents the minimum population size of turtles in Carmine Lake. The difference between the maximum and average numbers of turtles seen in 1992 ($n = 92$, $\bar{x} = 27.2$ turtles/interval) and maximum and average numbers of turtles seen in 1993 ($n = 147$, $\bar{x} = 40.0$) may be the result of greater visibility resulting from the placement of basking logs in the lake in 1992, although estimates imply a larger population size (Table VIII).

The low numbers of turtles observed water basking during an observation interval ($n_{\text{max}} = 30$) was probably related to the difficulty of distinguishing turtles from other surface objects and to fewer turtles at the water surface than were submerged or emergent basking.

Both Holland (1991) and Bury (1970) observed emergent basking behavior in western pond turtles. Like turtles at Hayfork Creek [California] (Bury 1970), turtles at Carmine Lake also showed a peak in basking at around 1000, but they did not show a second basking peak in the afternoon reported at other sites studied by Holland (1991). Similarly, Bury found that western pond turtles emergent basked at air temperatures between 10° and 38°C, but results indicated turtles preferred temperatures between 10° and 25°C. Furthermore, the basking peak was 20-25°C. Results substantiated Bury's finding that turtles often terminated emergent basking when air temperatures became too warm (>32°C).

Bury (1970) and Holland (1991) both reported that water basking became more prominent as air temperatures increased, particularly above 32°C. Although water basking was observed Carmine Lake, it remained relatively consistent with respect to air temperature. Wind speed appeared to have a greater effect on water basking than did air temperature.

Wind speed affected both emergent and water basking at Carmine Lake (Figure 13), but it has not been considered in previous studies on basking behavior of western pond turtles. Emergent basking dropped significantly with wind speeds ≥ 6 kph [4 mph], and no wind was preferred for emergent basking. The thermal advantage gained by water basking may be eliminated by excessive convective cooling at wind speeds > 6 kph. Water basking increased slightly at higher wind speeds (13 - 14 kph [8 - 9 mph]), but was still less than expected.

Turtles at Carmine Lake basked in much the same manner as those observed by Bury (1970) in a riverine system. Basking, particularly emergent basking, was most prominent at approximately 1000 hr. Turtles in Carmine Lake exhibited a preference for air temperatures between 20-25°C. They preferred to bask in no wind, but emergent basking continued until wind speed increased to 6 kph, after which emergent basking dropped significantly. Rain significantly reduced emergent basking.

TELEMETRY

Aquatic Home Range

Aquatic home ranges of turtles in Carmine Lake differed from those of turtles in riverine habitats. Riverine turtles exhibit linear home ranges along stretches of river (Bury 1970, Goodman 1997, Reese 1996). Adult turtles in Carmine Lake displayed relatively discrete ranges within a portion of the lake (Appendix D). Although some of these ranges overlapped, they were located throughout much of the lake and were generally centered in areas with abundant vegetation and basking sites nearby. Detailed analysis of telemetered turtle locations and habitat follows.

Movements

Movements observed at Carmine Lake consisted primarily of two types: daily short-term movements and long-term dispersal also described by: Bury (1970) at Hayfork Creek (tributary to the Trinity River [California]), Galen (1994) in a network of artificial canals and degraded streams in West Eugene [Oregon], Rathbun et al. (1993) in creeks and ponds along the Central California Coast, and Reese (1996) in the Trinity drainage [California]. Of the previously studied sites, Carmine Lake is the least disturbed and least river-associated site. All turtles tracked by telemetry were, by necessity, adult, and therefore, all observations apply only to adult western pond turtles at Carmine Lake and the surrounding area.

Three telemetered male turtles may have undertaken long-term movements, possibly as a result of capture and handling. Nevertheless, this study could not exclude

the possibility that the observed movements are part of a larger pattern of long-term movements associated with males. Turtles 7205, 7203, and 7249 left Carmine Lake within one week of being returned to Carmine Lake after capture. The turtles were located in July approximately 0.5 k [.3 mi] northwest at Castor Pond. Turtles 7203 and 7205 remained in Castor 1992-1993, but 7249 was relocated in Carmine Lake during the summer of 1993. Bury (1970) observed that males moved further than both females and juveniles during summer months. Reese (1996) observed similar active-season long-term movements, thought to be the result of adverse aquatic conditions or other environmental factors, but not associated with males *per se*.

Other authors (Holland 1991; Rathbun et al. 1993; Galen 1994; Reese 1996; Goodman 1997) have observed active-season terrestrial movements in females, primarily for the purpose of oviposition. Oviposition by the two radio-tagged gravid females was not observed. Grassy habitat, preferred for nesting (Holland 1991, 1994; Rathbun et al. 1993; Goodman 1997; and Kat Beal, U.S. Army Corps of Engineers, pers. comm.), surrounds Carmine Lake and occurs in patchy areas within the surrounding forest. Telemetered gravid females may have laid eggs very near Carmine Lake, or they may have made excursions between 2000 and 0800 the next morning, but these movements were undetected.

Short-term daily movements of the remaining seven females and four males occurred almost entirely within the aquatic habitat of Carmine Lake. Compared to turtles within riverine habitats (Bury 1970; Goodman 1997; Reese 1996), turtle movement was confined to a relatively small area. Each turtle displayed a relatively discreet home range

rather than the extensive linear home ranges displayed by riverine turtles (Bury 1970, Reese 1996).

Other authors described short-term distances moved by riverine turtles (Bury 1970, Holland 1991, Rathbun et al. 1993, Reese 1996), but the period between determination of turtle locations was much longer (i.e., a week or more) than the periods at Carmine Lake. Therefore, the reported distances were not directly comparable to the distances moved in a bi-hourly, daily, or overnight period at Carmine Lake (Table XII). In general, however, Carmine Lake turtles moved much shorter distances within the relatively confined area of the lake than the linear distances moved by riverine turtles. Bury (1970) determined that turtles moved 142 - 354 m/individual within summer months at Hayfork Creek, whereas Reese (1996) found that turtles moved 343 - 1412 m within the mainstem and south fork Trinity River. Contrary to Carmine Lake, both authors also found that males moved significantly further than females. Bury (1970) concluded that males moved an average of 3.87 - 2.44 times further than females, a greater difference observed with a greater number of relocations. Reese (1996) determined that males moved 1.7 times further than females on the south fork and 2.8 times further than females on the mainstem of the Trinity River.

It should be noted that the distances moved at Carmine Lake (Table XII) are minimum distances for the given time period because they are only measurements between initial and final determined locations. Travel was not necessarily in a straight line, and somewhat greater distances moved were likely.

HABITAT CHARACTERISTICS AND UTILIZATION

Several studies have examined some aspects of western pond turtle habitat use. Bury (1970) characterized basking sites at Hayfork Creek. Holland (1991) generally described aspects of habitat use with respect to life history. Goodman (1997) characterized nesting habitat of southwestern pond turtles in southern California. Reese (1996) characterized riverine and associated stillwater habitats in the Trinity drainage, California. This study examines the use of aquatic habitat in a relatively isolated stillwater habitat.

Distance to Shore

Turtles occurred more frequently than expected at sites 20-30 m from shore. Turtles > 50 m from shore provided an even greater contribution to differences between expected and actual frequencies, suggesting that turtles preferred sites as far from shore as possible. Boyer (1965) observed that freshwater turtles selected basking sites that were furthest from shore. This selection may be a terrestrial predator avoidance strategy.

Depth of Water

No consistent pattern was apparent in turtle occurrence within available water depths. Some of the intermediate depth classes were used more frequently than expected while others were not. The most shallow classes were avoided, perhaps because of their proximity to the shore. Most classes were not used significantly more or less than expected. This is in contrast to Bury's (1970) finding that riverine turtles used the deepest

pools (> 1.9 m) at Hayfork Creek. This may reflect the condition that depth per se is not a significant element of refuge habitat at Carmine Lake.

Type of Nearest Refugium

Although the most common type of refugium (excluding mud on the lake bottom) was submerged trees or snags, vegetated logs were used significantly more frequently than expected. Turtles are better able to conceal themselves within vegetation in and around vegetated logs while maintaining a distance from shore since many of these large logs protrude into the lake 20 m or more. Turtles can also bask on vegetated logs as well as use them for concealment, a condition for which only the latter is possible for submerged logs or snags. The differential use of potential refugia is not addressed by other authors.

Distance to Nearest Refugium

Although most turtles occurred within 10 m of refugia, they occurred in these sites less frequently than was expected. They occurred more frequently than expected at 20- < 30 m from potential refugia. Agonistic behavior has been observed in western pond turtles (Bury and Wolfheim 1973), and one alternative is that some turtles are being excluded from the proximity of refugia by the agonistic behavior of conspecifics. Turtles may also select their location based on other factors related to available refugia that were not measured.

Type of Basking Structure

Although other authors (Bury 1970; Bury and Wolfheim 1973; Holland 1991, 1994) addressed the importance of structures used for basking, such as logs, rocks, streambanks, old tires, none addressed preference for structure types. The most prevalent and frequently used basking structures in Carmine Lake were logs and snags that floated on or protruded from the surface of the lake. Vegetated logs were the next most available basking structure, but they were used significantly less frequently than expected.

Although these vegetated logs may serve well as refuge from predators or other threats, they would partially shade turtles and would probably be less than optimal basking structures. Other potential refugia found at Carmine Lake (boulders, bare dirt, or emergent vegetation) were not used significantly more or less frequently than expected.

Distance to Nearest Basking Structure

Similar to the results for distance of turtle occurrences from the nearest refugia, turtle occurred more frequently than expected 20-< 30 m from basking structures. They occurred somewhat less frequently than expected 10-< 20 m from basking structures. Occurrence at all other distances, including sites < 10 m, was not significantly more or less than expected. Turtles may have occurred 20-< 30 m more often than expected again because of agonistic interactions.

The fact that turtles occurred as often as expected <10 m from basking sites as opposed to refugia (where they occurred less frequently than expected) may be explained by agonistic behavior and competition for basking sites discussed by Bury and Wolfheim

(1973). Basking sites may serve as refugia, but not all refugia are basking sites (i.e., they may be submerged or have surfaces not conducive to basking). Turtles may be willing to relinquish their proximity to some structure used for refuge in Carmine Lake because the substrate is silty mud that may serve as a refugium. However, emergent basking can only be replaced by water basking, which is employed significantly less often than emergent basking (Figures 12, 13, and 14), probably because it is a much less efficient method of heat gain (Boyer 1965). Therefore, large adult turtles, such as those tracked in this study, may more aggressively defend their position on or near basking sites. They may be occurring near and using basking structures as much as possible given exclusion by other larger turtles and exclusion of smaller turtles. Evidence of this behavior exists in the aquatic home ranges (Appendix D) of the telemetered turtles. Most of them are centered around known basking sites within the lake.

Basking Structure Slope

Preferred slope of basking structures was unaddressed by previous studies. At Carmine Lake, turtles used structures with intermediate slopes of 20-30° more frequently than expected. Steeper or more shallow slopes were used no more or less frequently than expected. There may have been some selection of sites with intermediate slope to improve the likelihood of escape from predators without falling off the basking site. Steeper slopes may have been too steep for turtles to easily maintain a position. However, intermediate slopes would allow turtles to slide off a basking site with less effort than shallower slopes.

Basking Structure Aspect

Bury (1970) found that western pond turtles often oriented the posterior portion of their body toward the sun, presumably to manipulate thermal gain. He was unable to conclude whether this observation was the result of turtle behavior or basking site aspect. Turtles at Carmine Lake occurred more frequently than expected near sites that had south- or northeast-facing basking structures (Figure 23). They occurred less frequently than expected near level or southwest-facing sites. It should be noted that no sites with southeast or northwest aspects were available in Carmine Lake, and there were few sites that faced northeast ($n = 2$), east ($n = 3$), or southwest ($n = 2$). Selection of sites with easterly to southerly aspects and avoidance of westerly to northerly aspects would allow the greatest solar exposure at the times when the air is warm enough for emergent basking ($> 10-15^{\circ}\text{C}$).

Surface Area of Nearest Basking Structure

Patterns of use were not apparent in the frequency of turtle occurrence compared to the surface area classes of available basking structures in Carmine Lake. Observed turtle occurrences may have been the result of the frequency of occurrence contributed by individual turtles. For example, female #1786 occurred often on one basking site located at the north end of the lake (Appendix E). The estimated surface area of this basking structure is 7 m^2 . Of the 68 recorded turtle occurrences near basking sites with $7- < 8 \text{ m}^2$ surface area, 68% were contributed by #1786 at this basking site. Frequency of other turtles' occurrences near basking structures of various sizes was not significantly greater

or less than expected. Some of the apparent selection or avoidance of basking structures of the various size classes may have been the result of the contribution of individual turtles to the overall turtle occurrence and was not apparent in all of the turtles tracked. This basking selection or avoidance may be related to some unmeasured factor other than or in addition to size of the structure since no turtle occurrence patterns were apparent.

Vegetative Cover Type

The most abundant aquatic vegetative cover type was floating vegetation, and turtles' use of this type was no more or less than expected. However, this cover type was encountered at 93% of all of the sites. The only site with a mixture of floating and submerged rooted vegetation was the only site used significantly more frequently than expected, but 74% of all occurrences at this site were turtles 5524 and 1786 because the site was within their aquatic home ranges (Appendix D).

Amount of Vegetative Cover

Vegetative cover in the lake varied, but turtles used sites with >90% cover significantly more frequently than expected. This is likely due to the fact that the water that covered the floating vegetation at these sites was as much as 10°C warmer than water 10-25 cm below the surface. A thick mat of *Lemna trisulca* and other floating macrophytes occurred in these areas and allowed water to warm considerably at the surface while maintaining cooler water under the mat. This feature may allow turtles a finer thermoregulatory gradient in the water and may also allow turtles to maintain a suitable body temperature without basking on the water surface, particularly when air

temperatures are $> 25^{\circ}\text{C}$. Turtles also used sites with $>50\text{--}60\%$ cover more frequently than expected. This may be due to the fact that areas immediately surrounding basking sites often have reduced aquatic vegetation, possibly from turtles repeatedly entering and exiting the water around these sites. Less use than expected occurred at sites with $< 10\%$ or $> 40\text{--}50\%$ cover.

CONCLUSIONS

This study is one of few to focus on the ecology, habits, and habitat use in a stillwater environment. In addition, Carmine Lake is one of few lakes and ponds occupied by western pond turtles without substantial habitat alteration or introduction of exotic species which may prey on turtles. Information obtained by this study may help to better understand the biology of northwestern pond turtles in stillwater situations.

Based on mark and recapture data and visual observation analysis, it is apparent that sampling can be conducted under certain conditions to obtain optimum results. Capture should be conducted several times during the active season over short intervals. Where food resources are abundant, it is likely that manual capture will be required. The effectiveness of basking traps needs investigation. Visual observation can reveal presence or absence of turtles, but the variability of counts due to timing and environmental conditions make such observations unreliable for population estimation or trend analysis. To maximize the likelihood of detecting turtles, visual observations should be taken around 1000 hr when weather is dry, air temperatures are between 20-25°C, and wind is lacking.

Carmine Lake is unlikely to receive unusual predation and the site may resemble predation levels under historic conditions. The observed population structure is probably similar to what would have been found at undisturbed sites in the South Umpqua Basin and possibly other parts of the turtles' range. The observed population structure at

Carmine Lake supports the conclusion that western pond turtle populations may be naturally adult-biased.

Turtles at Carmine Lake exhibited decreasing growth rates with size, which likely represents most of a sigmoidal growth function. The only data that are lacking are the youngest age group (hatchlings), which likely have some of the fastest growth rates. Hatchlings are especially difficult to capture, much less recapture to obtain this data. Growth could use further study, especially to reveal interseasonal and between site differences. Variability across the range of the species may provide a fundamental understanding of geographic patterns and insights into populations or individuals within populations, including their relative health.

Turtles at Carmine Lake exhibited discreet home ranges and generally moved within a small area of the lake. Movements and home ranges determined for riverine sites by Bury (1970) and Reese (1996) are difficult to compare because the intervals between relocation were much longer, and they were based on linear distances moved within the stream corridor. However, short-term movements differed from those observed at riverine sites in that the movements and home ranges at Carmine Lake were generally shorter and confined to a smaller area. Some turtles may also undertake long-term movements, although the causal basis of these movements remains ambiguous. Although in this study, males may have moved in response to capture stress, it is also possible that the patterns observed were part of long-term movements that were the result of other causal factors.

Habitat use patterns were most apparent in response to distance from shore, depth of water, types of refugia and basking structures, and slope and aspect of basking structures. All turtles occurred less frequently than expected in depths < 25 cm and < 10 m from shore, probably to avoid predators. Turtles occurred more frequently than expected near refugia classified as vegetated logs and near basking structures classified as logs or snags. Vegetated logs would provide good protection as refugia but would at least partially shade turtles attempting to use them for emergent basking. Turtles occurred more frequently than expected near log or snags, possibly indicating that turtles position themselves closer to basking sites than to refugia. This may reinforce observations that turtles spend much of their time competing for and defending basking sites (Bury 1970), but further and experimental study of the basking refugium sites that can overlap in function needs address. Turtles appear to select basking structure with 20-30° slope, which would facilitate escape from predators as turtles return to water. Basking structures that faced east and south also appeared to be preferred over other aspects, probably providing basking turtles with the greatest possible solar exposure.

Patterns of use were not as obvious in distance to nearest refugium or basking site, surface area of nearest basking site, and amount and type of vegetative cover. Significantly more or less use of different classifications within these variables was usually attributable to the behavior one or a few turtles whereas occurrence was no more or less than expected for other turtles. These variables may be selected by an individual

but do not reveal general preferences of all turtles. Partial correlation analysis or experimental studies would help partition the interactions of these and other variables.

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APPENDIX A

**FISH AND WILDLIFE OBSERVED
AT CARMINE LAKE, 1992-1993**

Wildlife observed at Carmine Lake

(N = observed Nesting)

Fishes^{1/}

Mosquito fish (I)

Rainbow trout (I)

Gambusia affinis
*Oncorhynchus mykiss*Birds^{1/}

Great blue heron

Mallard

Wood duck (N)

Osprey

Peregrine falcon

Turkey vulture

Wild turkey

Common nighthawk

Rufous hummingbird

Belted kingfisher

Northern flicker (red-shafted)

Red-breasted sapsucker (N)

Hairy woodpecker

Pileated woodpecker (N)

Steller's jay

American crow

Common raven

Rock wren

Song sparrow

Dark-eyed junco

Yellow-headed blackbird (N)

Red-winged blackbird

Ardea herodias
Anas platyrhynchos
Aix sponsa
Pandion haliaetus
Falco peregrinus
Cathartes aura
Meleagris gallopavo
Chordeiles minor
Selasphorus rufus
Ceryle alcyon
Colaptes auratus
Sphyrapicus ruber
Picoides villosus
Dryocopus pileatus
Cyanocitta stelleri
Corvus brachyrhynchos
Corvus corax
Salpinctes obsoletus
Melospiza melodia
Junco hyemalis
Xanthocephalus xanthocephalus
*Agelaius phoeniceus*Amphibians^{2/}

Northwestern salamander

Pacific giant salamander

Pacific tree frog

Ambystoma gracile
Rhyacotriton tenebrosus
*Hyla regilla*Reptiles^{2/}

Northern alligator lizard

Southern alligator lizard

Western fence lizard

Western skink

Rubber boa

Elgaria coerulea
Elgaria multicarinata
Sceloporus occidentalis
Eumeces skiltonianus
Charina bottae

Racer

Gopher snake

Pacific Coast aquatic garter snake

Northwestern garter snake

Common garter snake

Western terrestrial garter snake

Western pond turtle

Mammals

Brush rabbit

California ground squirrel

Townsend chipmunk

American beaver

Gray fox

Black bear

Common raccoon

Striped skunk

Bobcat

Roosevelt elk

Black-tailed deer

*Coluber constrictor**Pituophis melanoleucus**Thamnophis atratus**Thamnophis ordinoides**Thamnophis sirtalis**Thamnophis elegans**Clemmys marmorata**Sylvilagus bachmani**Spermophilus beecheyi**Tamias townsendii**Castor canadensis**Urocyon cinereoargenteus**Ursus americanus**Procyon lotor**Mephitis mephitis**Lynx rufus**Cervus elaphus**Odocoileus hemionus*

APPENDIX B

**CARMINE LAKE USERS
22 MAY-4 AUGUST 1992**

Carmine Lake Users
May 22-August 4, 1992

Date	Activity				
	Camping	Fishing	Firearms	Wildlife watching	Hiking
5/22	3				
5/23	3				
5/24	3				
5/25	2				
5/26	2				
5/27	2				
5/28					
5/29					
5/31					
6/1					
6/2					
6/3					
6/4					
6/5					
6/6		2		1	
6/7		2		2	
6/8					
6/9					
6/10	3	2			
6/11					
6/12					
6/13					
6/14					
6/15					
6/16		3			
6/17					
6/18		3			
6/19					
6/20		2	3		
6/21					2
6/22					
6/23					
6/24					
6/25					
6/26					
6/27	5		2		
6/28					
6/29					

Date	Activity				
	Camping	Fishing	Firearms	Wildlife watching	Hiking
6/30					
6/31					
7/1					
7/2					
7/3	1	2	1		
7/4	5	7	1		
7/5	2	2			
7/6		6			
7/7		2			
7/8					
7/9					
7/10					
7/11					
7/12					
7/13					
7/14					
7/15					
7/16					
7/17					
7/18		3	3		2
7/19				5	
7/20					
7/21					
7/22					
7/23					
7/24					
7/25					
7/26					
7/27					
7/28					
7/29		1		8	
7/30					
7/31		2			
8/1				2	
8/2					
8/3					
8/4					
TOTALS	31	39	10	18	4

APPENDIX C
TURTLE CAPTURES AND RECAPTURES
1987-1993

APPENDIX C

TURTLE CAPTURES AND RECAPTURES, 1987-1993

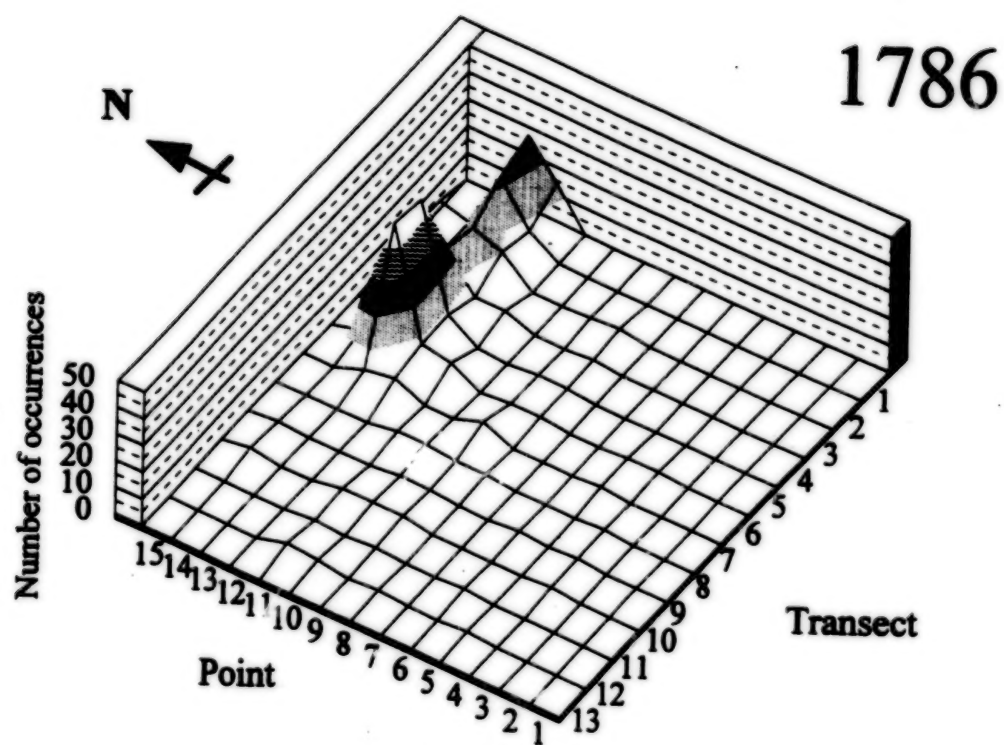
Year	Date	Number of captures (number of recaptures)							
		Males		Females		Subadults		Total	
		Captured	Recaptured	Captured	Recaptured	Captured	Recaptured	Captured	Recaptured
1987	30 July	2	(0)	3	(0)	1	(0)	6	(0)
1988	26 August	4	(0)	2	(0)	1	(0)	7	(0)
1989	15 June	2	(1)	2	(0)	5	(0)	9	(1)
1991	21 June	17	(1)	9	(1)	26	(0)	52	(2)
	5 August	4	(1)	1	(0)	2	(2)	7	(3)
1992	27-28 May	5	(0)	12	(7)	6	(2)	23	(9)
	02-03 June	5	(2)	12	(5)	5	(1)	22	(8)
	11 July	3	(2)	1	(0)	2	(1)	6	(3)
	04 August	3	(2)	0	(0)	2	(1)	5	(3)
1993	04-06 June	7	(4)	9	(4)	11	(4)	27	(12)
	26 June	2	(0)	1	(0)	6	(1)	9	(1)
	03-06 July	13	(5)	19	(6)	11	(4)	43	(15)
	24 July	0	(0)	0	(0)	1	(0)	1	(0)
	17	0	(0)	1	(0)	1	(0)	2	(0)
	01-09	x	(5)	x	(3)	x	(0)	23	(8)
	12 October	5	(2)	2	(2)	4	(1)	11	(5)
TOTAL		72	(25)	74	(28)	84	(17)	253	(70)

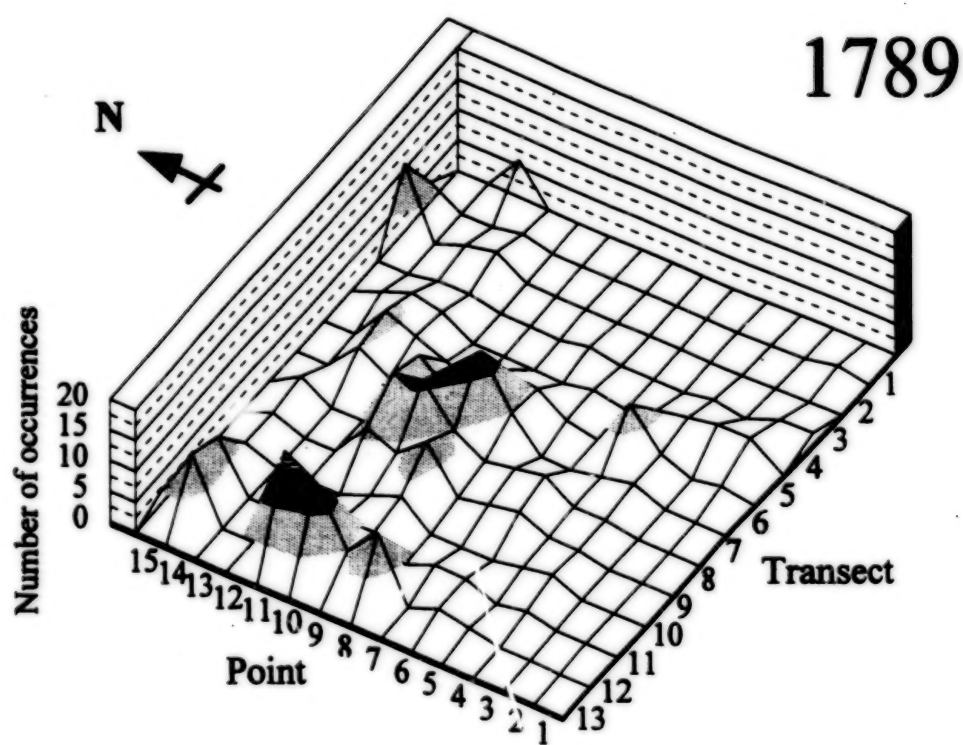
x = unknown, observer error in sexual classification of captured individuals.

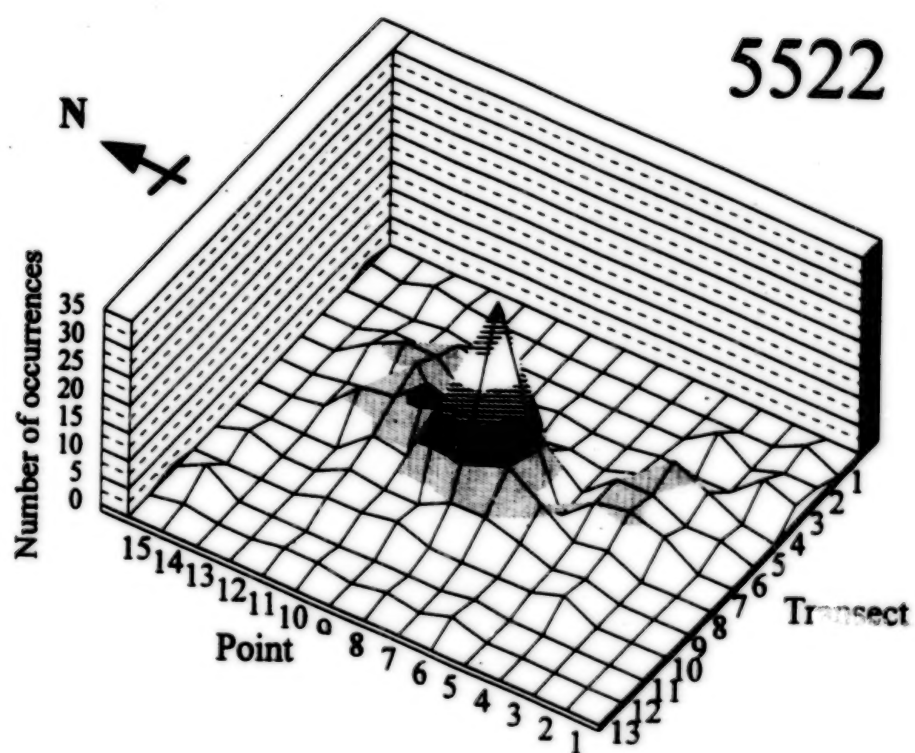
145

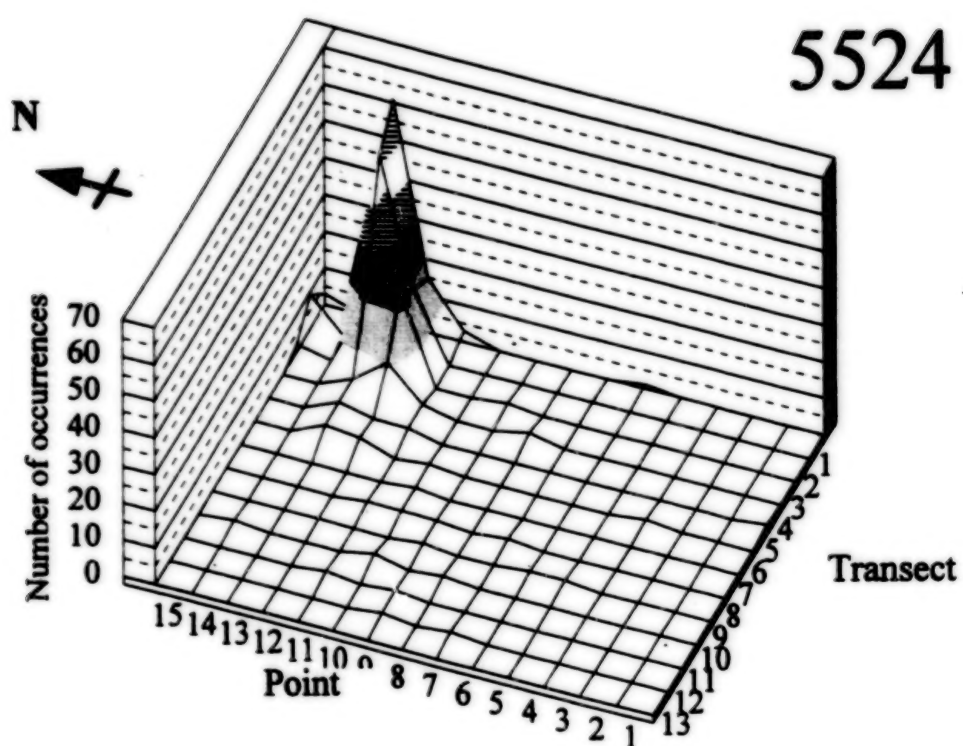
APPENDIX D

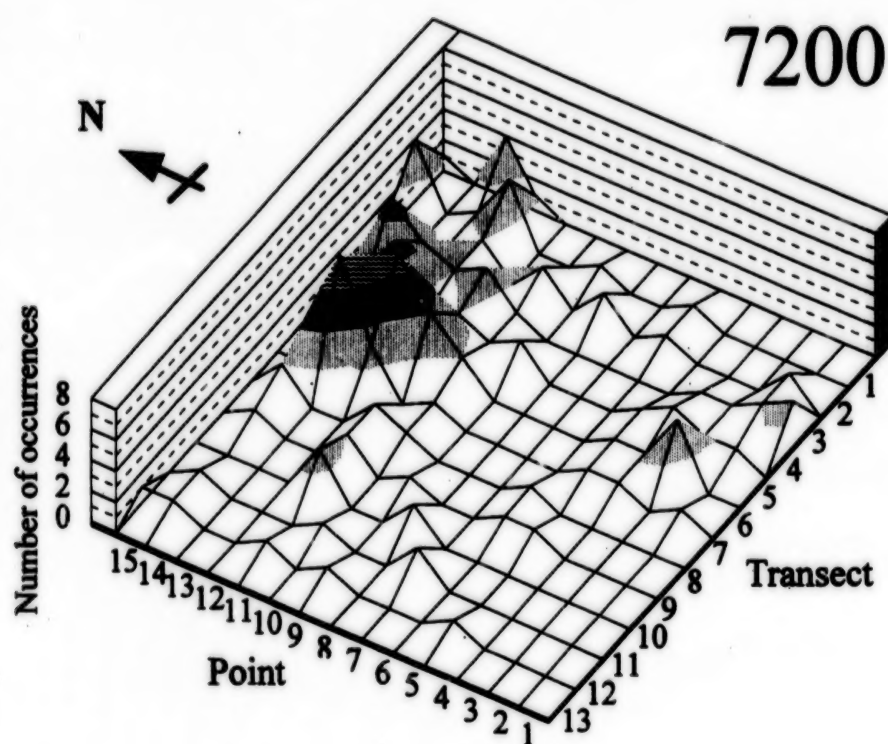
**HOME RANGES OF NORTHWESTERN POND TUPTLES
AT CARMINE LAKE, 1992**

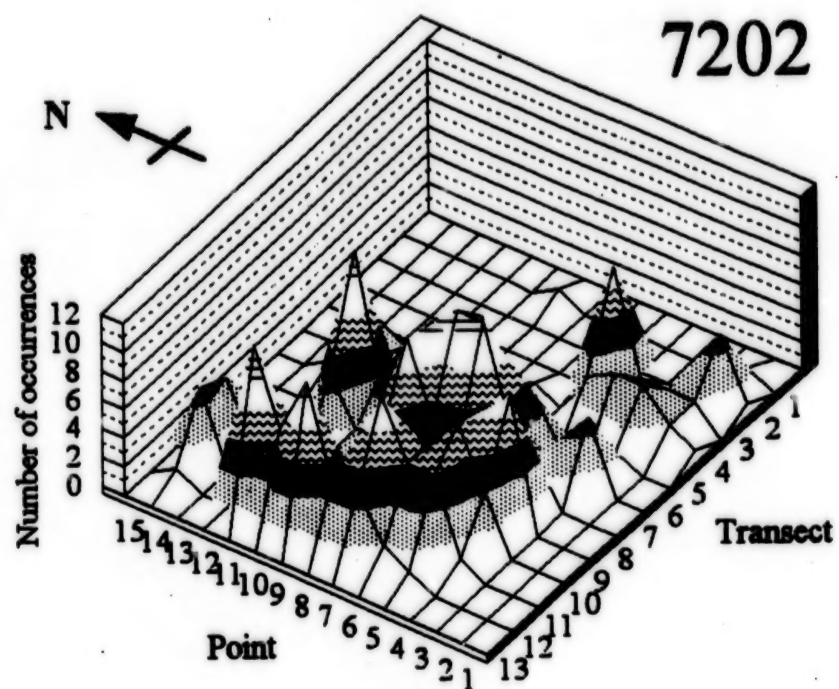


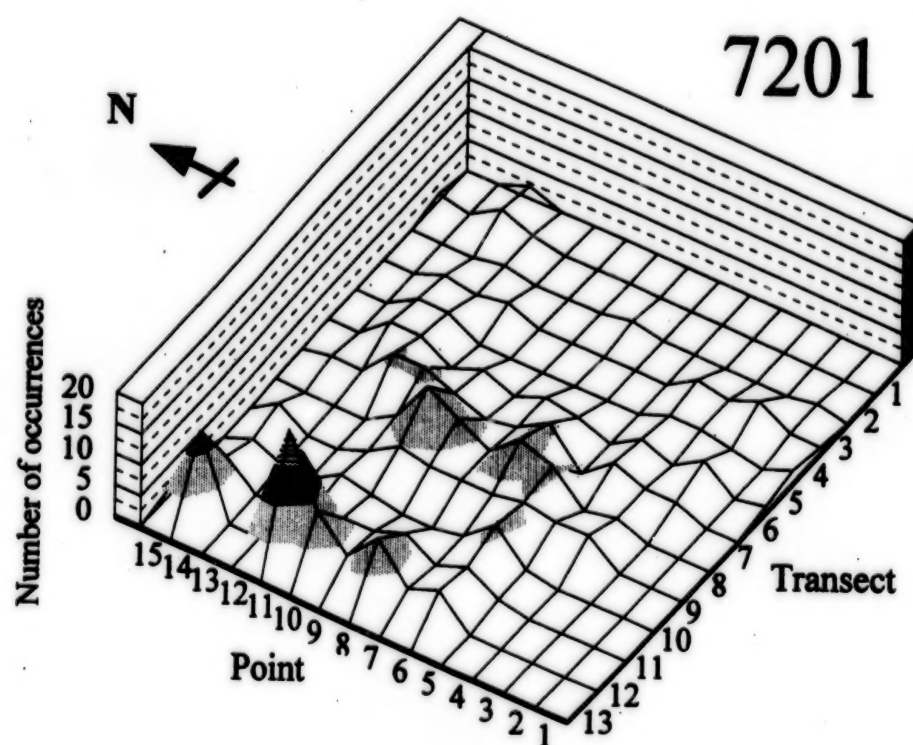


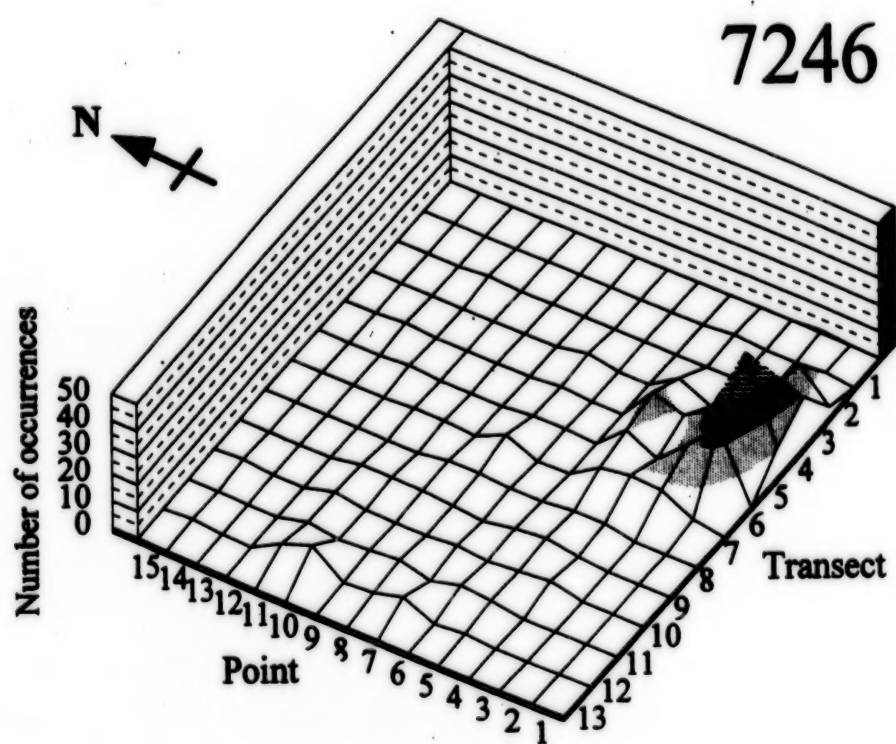


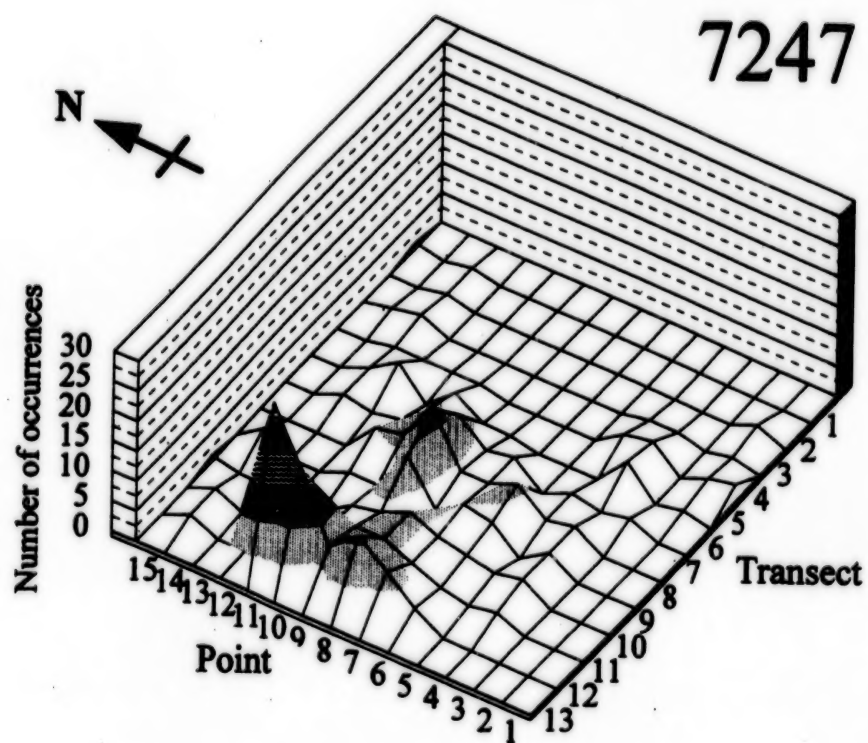


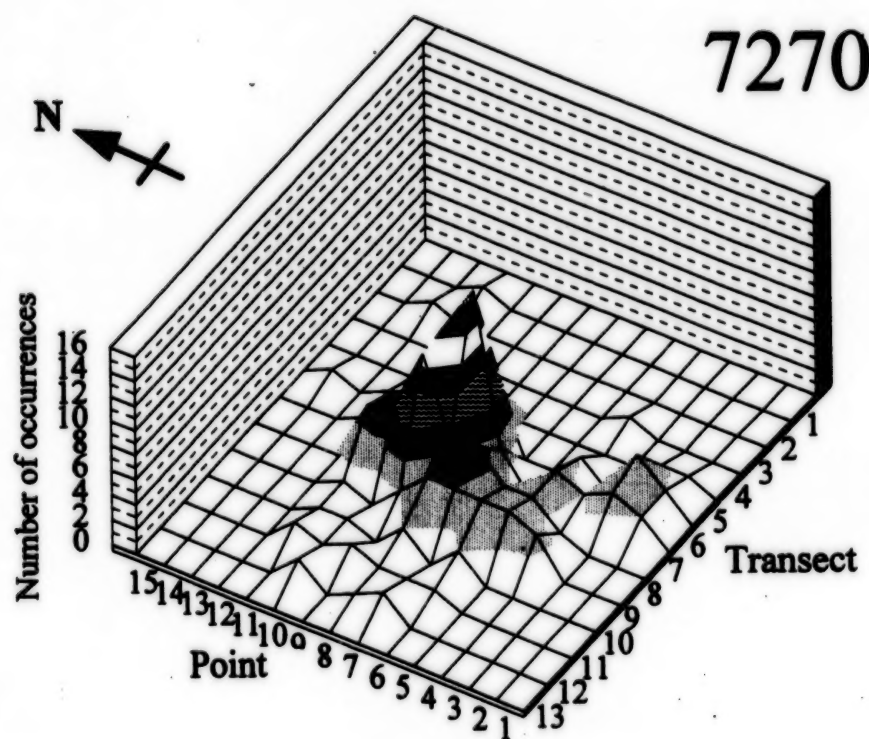


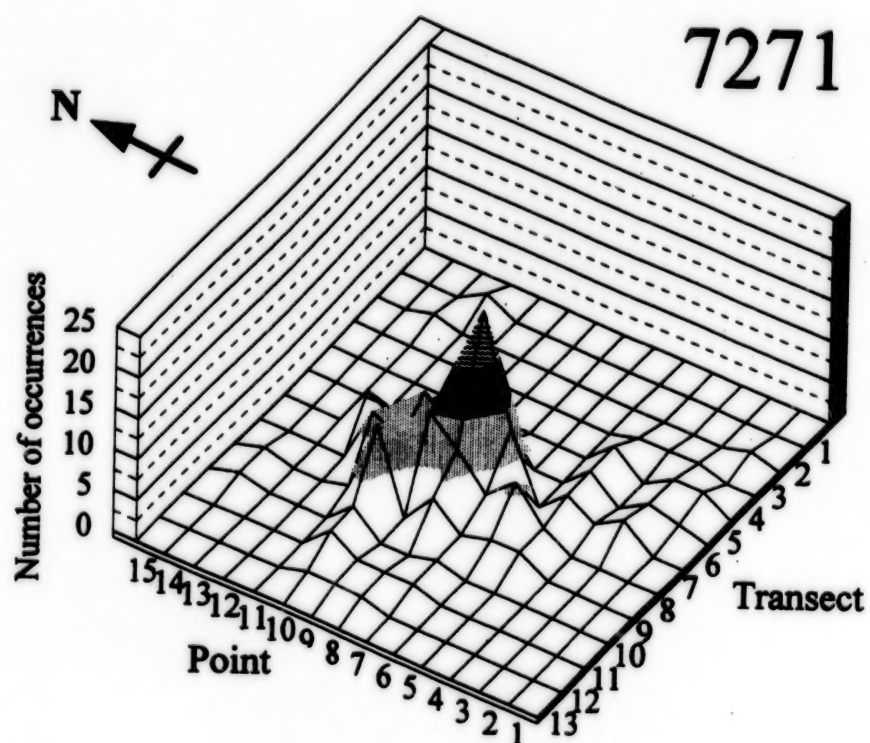












APPENDIX E
HABITAT UTILIZATION DATA AND ANALYSIS

df=5	critical value =					
	11.07					
Distance to shore	TO	Turtles	HO	Habitat	TO(exp)	Chi-square
<10	420	0.13	36	0.27	842	211.60 <<
10-<20	1076	0.34	41	0.30	959	14.25 >
20-<30	574	0.18	24	0.18	561	0.28 -
30-<40	497	0.16	20	0.15	468	1.82 -
40-<50	380	0.12	11	0.08	257	58.49 <
50-<60	211	0.07	3	0.02	70	282.56 >>
n =	3158		135			569.02

TO = Observed (actual) turtle occurrence

Turtles = Proportion of turtle occurrences per variable category

HO = Habitat occurrence

Habitat = Proportion of observed habitat available

TO(exp) = Expected turtle occurrence if turtles occurred in the same proportions as available habitat

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Distance to shore

DTS	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271 TO	HO	HO%	
<10	48	67	21	58	32	67	20	23	72	6	6	420	36	0.27
10-<20	205	127	66	142	55	123	116	75	121	28	18	1076	41	0.30
20-<30	82	42	52	112	20	55	65	52	48	23	23	574	24	0.18
30-<40	34	58	65	8	29	56	75	39	66	34	32	496	20	0.15
40-<50	12	54	72	4	3	49	51	9	42	38	46	380	11	0.08
>50	2	12	65	1	0	14	20	9	19	31	38	211	3	0.02
	383	360	341	325	139	364	347	207	368	160	163	3157	135	
Expected	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271 All			
<10	102	96	91	87	37	97	93	55	98	43	43	842		
10-<20	116	109	104	99	42	111	105	63	112	49	50	959		
20-<30	68	64	61	58	25	65	62	37	65	28	29	561		
30-<40	57	53	51	48	21	54	51	31	55	24	24	468		
40-<50	31	29	28	26	11	30	28	17	30	13	13	257		
>50	9	8	8	7	3	8	8	5	8	4	4	70		
Chi-square	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271 All			
<10	28.69	8.76	53.78	9.48	0.69	9.31	56.86	18.78	6.96	31.51	32.29	211.40		
10-<20	67.61	2.85	13.62	18.99	3.87	1.40	1.07	2.34	0.76	8.73	20.05	14.33		
20-<30	2.84	7.56	1.23	50.89	0.90	1.46	0.18	6.28	4.64	1.04	1.23	0.29		
30-<40	9.11	0.41	4.15	33.48	3.43	0.08	10.83	2.26	2.42	4.47	2.55	1.71		
40-<50	11.82	20.74	70.36	19.09	6.12	12.61	18.27	3.67	4.81	47.80	80.60	58.59		
>50	4.98	2.00	435.13	5.36	3.09	4.32	19.58	4.21	14.32	211.84	326.27	282.76		

Individual occurrences

Habitat Characteristics and Use

161

df=10, p=0.05 crit. val.=19.075

Depth of Water (m)	TO	Turtles	HO	Habitat	TO(erp)	Chi-square
0-0.25	88	0.03	13	0.10	304	153.57 <<
0.25-0.5	137	0.04	8	0.06	187	13.43 .
0.5-0.75	447	0.14	13	0.10	304	67.15 >
0.75-1.0	289	0.09	10	0.07	234	12.97 .
1.0-1.25	380	0.12	15	0.11	351	2.42 .
1.25-1.5	418	0.13	20	0.15	468	5.31 .
1.5-1.75	767	0.24	37	0.27	866	11.22 .
1.75-2.0	438	0.14	12	0.09	281	88.13 >
2.0-2.25	75	0.02	4	0.03	94	3.69 .
2.25-2.5	57	0.02	1	0.01	23	48.28 >
>2.5	62	0.02	2	0.01	47	4.95 .
n =	3158		135			411.11

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Depth of Water

DW Class	1786	1789	5522	5524	7280	7281	7282	7246	7247	7270	7271 TO	HO	Habitat %	
0-<0.25	15	25	4	12	10	10	4	1	4	1	2	88	13	0.10
0.25-<0.5	64	6	8	22	12	9	7	4	4	1	0	137	8	0.06
0.5-<0.75	128	35	16	191	25	19	7	9	9	3	5	447	13	0.10
0.75-<1.0	79	30	12	68	18	21	18	13	22	4	4	289	10	0.07
1.0-<1.25	15	49	43	9	23	69	24	47	89	8	4	388	15	0.11
1.25-<1.5	27	65	31	6	19	64	39	36	81	18	12	418	20	0.15
1.5-<1.75	41	91	117	10	21	99	133	45	88	99	62	766	37	0.27
1.75-<2.0	12	47	78	7	8	45	63	19	50	51	58	438	12	0.09
2.0-<2.25	0	1	19	0	1	14	16	2	8	5	9	75	4	0.03
2.25-<2.5	1	1	6	0	0	9	13	8	10	8	1	57	1	0.01
>2.5	1	10	7	0	2	5	3	23	3	2	6	62	2	0.01
Sum	383	360	341	325	139	364	347	207	368	160	163	3157	135	

Expected Frequency

DW Class	1786	1789	5522	5524	7280	7281	7282	7246	7247	7270	7271 AB	
0-<0.25	37	35	33	31	13	35	33	20	35	15	16	304
0.25-<0.5	23	21	20	19	8	22	21	12	22	9	10	187
0.5-<0.75	37	35	33	31	13	35	33	20	35	15	16	304
0.75-<1.0	28	27	25	24	10	27	26	15	27	12	12	234
1.0-<1.25	43	40	38	36	15	40	39	23	41	18	18	351
1.25-<1.5	57	53	51	48	21	54	51	31	55	24	24	468
1.5-<1.75	105	99	93	89	38	100	95	57	101	44	45	865
1.75-<2.0	34	32	30	29	12	32	31	18	33	14	14	281
2.0-<2.25	11	11	10	10	4	11	10	6	11	5	5	94
2.25-<2.5	3	3	3	2	1	3	3	2	3	1	1	23
>2.5	6	5	5	5	2	5	5	3	5	2	2	47
Sum	383	360	341	325	139	364	347	207	368	160	163	3157

Chi Square Values

DW Class	1786	1789	5522	5524	7280	7281	7282	7246	7247	7270	7271 AB	
0-<0.25	12.98	2.70	25.32	11.90	0.86	17.90	25.89	17.98	27.89	13.47	11.95	153.48
0.25-<0.5	75.17	11.82	7.37	8.39	1.72	7.33	8.95	5.57	14.54	7.59	9.66	13.41
0.5-<0.75	225.12	0.00	8.63	814.96	10.88	7.35	20.88	6.88	19.72	9.99	7.29	67.26
0.75-<1.0	90.35	0.42	6.96	88.15	5.76	1.32	2.31	0.36	1.01	5.20	5.40	13.01
1.0-<1.25	17.84	2.05	0.69	28.35	3.70	20.16	5.50	25.04	56.61	5.38	10.99	2.43
1.25-<1.5	15.99	2.55	7.54	36.90	0.12	1.88	1.12	0.93	12.86	1.37	6.11	5.28
1.5-<1.75	38.98	0.68	5.93	78.20	7.67	0.81	15.10	2.43	1.64	5.25	6.72	11.39
1.75-<2.0	14.27	7.05	75.03	16.59	1.54	4.94	33.52	0.82	9.14	95.11	130.67	88.26
2.0-<2.25	11.35	8.76	7.83	9.63	2.36	0.96	3.18	2.79	0.77	0.81	3.68	3.67
2.25-<2.5	1.19	1.04	4.73	2.41	1.83	14.74	42.32	27.27	19.41	39.19	8.04	48.32
>2.5	3.85	4.88	0.75	4.81	0.88	0.83	0.89	129.57	1.10	0.86	5.32	4.96
	586.70	48.23	158.84	1668.28	34.84	76.61	159.65	217.93	164.70	182.60	197.75	411.47

Individual occurrences

Habitat Characteristics and Use

163

df=2, p=0.05		crit. val.=5.99					
Type of Refugeum	TO	Turtles	HO	Habitat	TO(exp)	Chi-Square	
Undercut bank	168	0.05	8	0.06	187	1.96 -	
Submerged tree/snag	1784	0.56	85	0.63	1988	21.01 <	
Vegetated log	1206	0.38	42	0.31	982	50.85 >>	
n =	3158		135				

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Type of Nearest Refugium

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	TO	HO	Habitat %
Type of Refugium	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	TO	HO	Habitat %
Undercut bank	4	25	31	1	7	13	14	43	17	4	9	168	8	0.06
Submerged tree/snag	343	186	164	314	109	167	167	79	128	67	59	1783	85	0.63
Vegetated log	36	149	146	10	23	184	166	85	223	89	95	1206	42	0.31
Sum	383	360	341	325	139	364	347	207	368	160	163	3157	135	
Expected frequency														
Type of Refugium	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All		
Undercut bank	23	21	20	19	8	22	21	12	22	9	10	187		
Submerged tree/snag	241	227	215	205	88	229	218	130	232	101	103	1988		
Vegetated log	119	112	106	101	43	113	108	64	114	50	51	982		
Sum	383	360	341	325	139	364	347	207	368	160	163	3157		
Chi Square Values														
Type of Refugium	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All		
Undercut bank	15.40	0.63	5.76	17.31	0.19	3.41	2.09	77.00	1.06	3.17	0.04	1.95		
Submerged tree/snag	43.02	7.30	11.97	58.46	5.27	16.87	12.13	20.22	46.41	11.30	18.55	21.09		
Vegetated log	58.03	12.22	15.01	82.10	9.48	44.21	31.21	6.59	102.85	30.91	38.68	51.01		
Sum	116.45	20.15	32.75	157.87	14.94	64.49	45.43	103.81	150.32	45.37	57.27	74.04		

Individual occurrences

Habitat Characteristics and Use

165

df=5, p=0.05 crit. val.=11.07

Distance to nearest refugium (m)	TO	Turtles	HO	Habitat	TO(exp)	Chi-square
0<10	1642	0.52	78	0.58	1825	18.28 <
10<20	658	0.21	30	0.22	702	2.73 -
20<30	655	0.21	18	0.13	421	129.97 >>
30<40	142	0.04	7	0.05	164	2.89 -
40<50	28	0.01	1	0.01	23	0.91 -
>50	33	0.01	1	0.01	23	3.95 -
n=	3158		135			

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Distance to Nearest Refugium

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	TO	HO	Habitat %
DNR class	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271			
0-<10	297	201	106	271	90	170	122	117	196	37	35	1642	78	0.58
10-<20	50	67	92	40	28	86	102	57	60	43	33	658	30	0.22
20-<30	28	67	122	10	13	84	87	18	80	69	76	654	18	0.13
30-<40	6	13	17	3	7	15	31	11	21	9	9	142	7	0.05
40-<50	1	4	2	0	0	5	2	2	2	0	10	28	1	0.01
>50	1	8	2	1	1	4	3	2	9	2	0	33	1	0.01
Sum	383	360	341	325	139	364	347	207	368	160	163	3157	135	

Expected frequency

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	All	
DNR class	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All	
0-<10	221	208	197	188	80	210	200	120	213	92	94	1824	
10-<20	85	80	76	72	31	81	77	46	82	36	36	702	
20-<30	51	48	45	43	19	49	46	28	49	21	22	421	
30-<40	20	19	18	17	7	19	18	11	19	8	8	164	
40-<50	3	3	3	2	1	3	3	2	3	1	1	23	
>50	3	3	3	2	1	3	3	2	3	1	1	23	
Sum	383	360	341	325	139	364	347	207	368	160	163	3157	

Chi Square Values

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	All	
DNR class	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All	
0-<10	25.90	0.24	42.05	36.88	1.17	7.73	30.73	0.06	1.30	33.25	37.19	18.17	
10-<20	14.48	2.11	3.47	14.38	0.27	0.32	8.03	2.63	5.80	1.56	0.29	2.70	
20-<30	10.42	7.52	128.83	25.64	1.65	25.92	35.86	3.34	19.50	106.51	135.50	129.05	
30-<40	9.67	1.72	0.03	11.39	0.01	0.80	9.40	0.01	0.19	0.06	0.04	2.88	
40-<50	1.19	0.67	0.11	2.41	1.03	1.97	0.13	0.14	0.19	1.19	64.03	0.91	
>50	1.19	10.67	0.11	0.82	0.00	0.63	0.07	0.14	14.44	0.56	1.21	3.95	
	50.81	9.87	174.35	76.90	3.09	33.97	74.62	6.03	26.60	141.32	172.97	149.92	

Individual occurrences

Habitat Characteristics and Use

167

df = 4, p=0.05Crit.
=9.488 val.

Type of banking site	TO	Turtles	HO	Habitat	TO(exp)	Chi-square
Boulder	164	0.05	11	0.08	257	33.84 <<
Dirt	33	0.01	1	0.01	23	3.95 -
Log/mag	1940	0.61	69	0.51	1614	65.81 >>
Emergent vegetation	170	0.05	7	0.05	164	0.00 -
Vegetated log	851	0.27	47	0.35	1099	56.14 <<
n=	3158		135	Sum		159.74

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Type of Nearest Basking Structure

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	NO	Habitat %
Type of ha	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271		
Boulder	4	23	29	1	9	11	12	43	19	4	9	164	11
Diet	0	4	4	0	1	1	4	16	0	1	2	33	1
Log/mag	322	227	169	256	96	227	214	78	200	79	71	1999	69
Emergent	29	9	25	51	11	10	3	2	12	7	11	170	7
Vegetated	28	97	114	17	22	115	114	68	137	69	70	851	47
Sum	383	360	341	325	139	364	347	207	368	160	163	3157	135

Expected frequency

Type of ha	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All
Boulder	31	29	28	26	11	30	28	17	30	13	19	257
Diet	3	3	3	2	1	3	3	2	3	1	1	23
Log/mag	196	184	174	166	71	186	177	106	188	82	83	1614
Emergent	20	19	18	17	7	19	18	11	19	8	8	164
Vegetated	133	125	119	113	48	127	121	72	128	56	57	1099
Sum	383	360	341	325	139	364	347	207	368	160	163	3157

Chi Square Values

Type of ha	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All
Boulder	23.72	1.37	0.05	24.52	0.48	11.74	9.37	40.49	4.02	6.26	1.38	33.79
Diet	2.84	0.67	0.86	2.41	0.00	1.07	0.80	136.49	2.73	0.03	0.52	3.95
Log/mag	81.42	10.05	0.16	48.64	8.77	9.02	7.57	7.30	0.75	0.09	1.82	66.63
Emergent	4.21	5.01	3.03	69.20	2.00	4.17	12.49	7.11	2.63	0.20	0.77	0.24
Vegetated	83.22	6.41	0.19	81.70	14.39	1.08	0.38	0.23	0.62	3.17	3.09	56.01

Individual occurrences

168

Habitat Characteristics and Use

169

df=5, p=0.05		crit. value=11.07				
Distance to nearest basking site	TO	Turtles	HO	Habitat	TO(exp)	Chi-square
<10	1383	0.44	60	0.44	1404	0.30 _
10-20	854	0.27	41	0.30	959	11.52 <
20-30	636	0.20	21	0.16	491	42.66 >>
30-40	224	0.07	11	0.08	257	4.31 _
40-50	28	0.01	1	0.01	23	0.91 _
50+	33	0.01	1	0.01	23	3.95 _
n =	3158		135			

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Distance to Nearest Basking Structure

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	TO	HO	Habitat %
DNB	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271			
<10	166	174	152	36	48	180	170	100	224	71	64	1386	60	0.44
10-<20	859	859	859	859	859	859	859	859	859	859	859	859	41	0.30
20-<30	639	639	639	639	639	639	639	639	639	639	639	639	21	0.16
30-<40	227	227	227	227	227	227	227	227	227	227	227	227	11	0.08
40-<50	28	28	28	28	28	28	28	28	28	28	28	28	1	0.01
50+	20	20	20	20	20	20	20	20	20	20	20	20	1	0.01
Sum	1939	1947	1925	1809	1821	1953	1943	1873	1997	1844	1837	3159	135	

Expected frequency

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	All
DNB	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All
<10	862	865	856	804	809	868	864	832	888	820	816	1404
10-<20	589	591	585	549	553	593	590	569	606	560	558	959
20-<30	302	303	299	281	283	304	302	291	311	287	286	491
30-<40	158	159	157	147	148	159	158	153	163	150	150	257
40-<50	14	14	14	13	13	14	14	14	15	14	14	23
50+	14	14	14	13	13	14	14	14	15	14	14	23
Sum	1939	1947	1925	1809	1821	1953	1943	1873	1997	1844	1837	3159

Chi Square Values

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	All
DNB	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All
<10	561.75	552.32	578.56	733.61	716.18	545.33	557.02	644.46	496.09	683.71	693.46	0.23
10-<20	123.90	121.18	128.76	174.47	169.26	119.17	122.54	148.01	105.13	159.60	162.50	10.51
20-<30	377.37	373.05	385.04	454.43	446.74	369.85	375.21	414.81	347.08	432.34	436.67	44.33
30-<40	30.14	29.45	31.37	42.99	41.66	28.94	29.80	36.26	25.39	39.20	39.94	3.59
40-<50	12.95	12.78	13.24	15.91	15.61	12.66	12.87	14.38	11.79	15.06	15.22	0.90
50+	2.21	2.16	2.31	3.25	3.14	2.12	2.18	2.70	1.83	2.94	3.00	0.49

Individual occurrences

Habitat Characteristics and Use

171

df=4, p=0.05 crit. val. = 9.488						
Slope of basking site (degrees)	TO	Turtles	HO	Habitat	TO(exp)	Chi-square
<10	1847	0.58	81	0.60	1895	1.21 -
10-20	907	0.29	41	0.30	959	2.83 -
20-30	315	0.10	9	0.07	211	51.84 >>
30-40	0	0.00	0	0.00	0	0.00 -
40+	89	0.03	4	0.03	94	0.22 -
n=	3158		135			56.10

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Slope of Nearest Basking Structure

	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TO	HO	Habitat %	
Slope class (in	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271				
<10	262	211	139	253	67	201	195	132	247	71	69		1847	81	0.60
10<20	91	103	112	66	60	120	109	64	91	51	40		907	41	0.30
20<30	22	28	80	2	8	37	28	11	22	30	46		314	9	0.07
30<40	0	0	0	0	0	0	0	0	0	0	0		0	0	0.00
40+	8	18	10	4	4	6	15	0	8	8	8		89	4	0.03
Sum	383	360	341	325	139	364	347	207	368	160	163		3157	135	
Expected TO	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All			
<10	230	216	205	195	83	218	208	124	221	96	98		1894		
10<20	116	109	104	99	42	111	105	63	112	49	50		959		
20<30	26	24	23	22	9	24	23	14	25	11	11		210		
30<40	0	0	0	0	0	0	0	0	0	0	0		0		
40+	11	11	10	10	4	11	10	6	11	5	5		94		
Chi-squares	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All			
<10	4.51	0.12	21.03	17.25	3.22	1.39	0.84	0.49	3.11	6.51	8.48		66.95		
10<20	5.51	0.37	0.69	10.84	7.49	0.81	0.12	0.02	3.86	0.12	1.82		31.65		
20<30	0.49	0.67	144.26	17.85	0.17	6.68	1.02	0.57	0.26	35.04	113.99		320.61		
30<40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00		
40+	0.99	5.04	0.00	3.29	0.00	2.12	2.17	6.13	0.77	2.24	2.08		24.84		
Sum	11.50	6.19	165.98	49.23	10.89	11.00	4.15	7.21	8.00	43.91	125.98		444.05		

Individual occurrences

Habitat Characteristics and Use

173

df=8, P=0.05 Crit. value=15.51

Basking site aspect	TO	Turtles	HO	Habitat	TO(exp)	Chi-square
N	776	0.25	36	0.27	842	5.19 -
NE	95	0.03	2	0.01	47	49.69 >
E	40	0.01	3	0.02	70	12.98 -
SE	0	0.00	0	0.00	0	
S	937	0.30	28	0.21	655	121.42 >>
SW	42	0.01	2	0.01	47	0.49 -
W	153	0.05	10	0.07	234	28.00 <
NW	0	0.00	0	0.00	0	
No Aspect	1115	0.35	54	0.40	1263	17.39 <
n=	3158		135	Sum		235.15

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Aspect of Nearest Building Structure

Aspect	TURTLE_0	TURTLE_0	TURTLE_0	TURTLE_0	TURTLE_0	TURTLE_0	TURTLE_0	TURTLE_0	TURTLE_0	TURTLE_0	TURTLE_0	TO	NO	Relative %
N	82	79	126	27	30	80	87	89	68	42	45	775	36	0.27
NE	33	19	0	32	2	5	1	0	3	0	0	95	2	0.04
E	5	5	4	10	4	4	5	1	1	0	1	48	3	0.02
SE	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
S	126	83	97	230	42	80	67	25	71	53	63	997	28	0.21
SW	0	4	4	0	2	5	6	17	0	1	3	42	2	0.04
W	4	31	11	5	7	31	30	7	23	3	1	173	10	0.07
NW	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
No Aspect	133	139	99	21	32	139	151	48	282	61	50	1115	54	0.40
Sum	383	388	341	325	139	364	347	287	368	168	163	3157	135	

Expected Frequency

Aspect	1786	1789	5522	5534	7280	7281	7282	7246	7247	7270	7271	AB	
N	102	96	91	87	37	97	99	35	98	43	43	842	
NE	6	5	5	5	2	5	5	3	5	2	2	47	
E	9	8	8	7	3	8	8	5	8	4	4	70	
SE	0	0	0	0	0	0	0	0	0	0	0	0	
S	79	75	71	67	29	75	72	43	76	33	34	655	
SW	6	5	5	5	2	5	5	3	5	2	2	47	
W	28	27	25	24	10	27	26	15	27	12	12	234	
NW	0	0	0	0	0	0	0	0	0	0	0	0	
No Aspect	153	144	136	130	56	146	139	83	147	64	65	1263	
Sum	383	388	341	325	139	364	347	287	368	168	163	3157	

Chi Square Values

Aspect	1786	1789	5522	5534	7280	7281	7282	7246	7247	7270	7271	AB	
N	3.97	3.81	13.52	41.88	4.51	3.88	0.33	28.78	9.25	0.81	0.85	99.44	
NE	131.88	35.82	5.85	153.49	0.88	0.88	3.34	3.87	1.18	2.37	2.41	337.48	
E	1.45	1.13	1.89	1.87	0.27	2.87	0.95	2.82	6.38	3.56	1.98	23.19	
SE	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	
S	27.29	8.95	9.76	392.19	6.82	0.27	0.34	7.49	0.37	11.83	25.21	481.78	
SW	5.67	0.33	0.22	4.81	0.88	0.88	0.14	63.31	5.45	0.79	0.14	88.91	
W	28.95	8.78	8.85	15.11	1.86	0.88	0.72	4.53	0.67	6.61	18.16	89.14	
NW	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	
No Aspect	2.66	0.17	10.25	91.39	10.82	1.23	1.87	2.65	25.48	0.14	3.54	143.54	
Sum	198.92	41.12	78.28	687.75	11.86	6.88	5.82	181.91	23.14	25.17	39.87	1891.86	

Individual occurrences

Habitat Characteristics and Use

175

df=8, p=0.05

crit. value=15.51

Surface area of nearest basking site (sq. m)	TO	Turtles	HO	Habitat	TO(esp)	Chi-square
<1	733	0.23	30	0.22	702	1.39 -
1 - <2	501	0.16	22	0.16	515	0.36 -
2 - <3	285	0.09	11	0.08	257	2.98 -
3 - <4	433	0.14	24	0.18	560	29.38 <
4 - <5	406	0.13	14	0.10	327	18.82 >
5 - <6	454	0.14	12	0.09	280	106.97 >>
6 - <7	94	0.03	7	0.05	164	29.71 <
7 - <8	68	0.02	1	0.01	23	85.06 >
8+	184	0.06	14	0.10	327	62.87 <
Sum	3158		135	Sum		337.54

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Surface Area of Nearest Basking Structure

	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TURTLE_#	TO	HO	Habitat %
SABS	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271			
<1	68	76	104	31	39	90	111	26	83	55	49	732	30	0.22
1-2	92	63	21	57	23	70	49	25	68	15	18	501	22	0.16
2-3	39	30	33	35	20	37	9	10	53	8	11	285	11	0.08
3-4	40	63	45	62	15	54	44	50	40	7	13	433	24	0.18
4-5	16	53	37	11	9	60	64	51	68	21	16	406	14	0.10
5-6	71	49	33	120	20	29	36	5	42	26	23	454	12	0.09
6-7	1	3	12	0	2	9	22	28	5	6	6	94	7	0.05
7-8	46	4	4	4	5	3	0	1	1	0	0	68	1	0.01
8+	10	19	52	5	6	12	12	11	8	22	27	184	14	0.10
Sum	383	360	341	325	139	364	347	207	368	160	163	3157	135	
Expected TO	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All		
<1	85	80	76	72	31	81	77	46	82	36	36	702		
1-2	62	59	56	53	23	59	57	34	60	26	27	514		
2-3	31	29	28	26	11	30	28	17	30	13	13	257		
3-4	68	64	61	58	25	65	62	37	65	28	29	561		
4-5	40	37	35	34	14	38	36	21	38	17	17	327		
5-6	34	32	30	29	12	32	31	18	33	14	14	281		
6-7	20	19	18	17	7	19	18	11	19	8	8	164		
7-8	3	3	3	2	1	3	3	2	3	1	1	23		
8+	40	37	35	34	14	38	36	21	38	17	17	327		
Sum	383	360	341	325	139	364	347	207	368	160	163			
Chi-square	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All		
<1	3.44	0.20	10.51	23.53	2.13	1.03	14.89	8.70	0.02	10.63	4.51	1.32116		
1-2	14.02	0.32	21.51	0.31	0.01	1.92	1.01	2.26	1.08	4.70	2.76	0.35289		
2-3	1.95	0.02	0.98	2.74	6.64	1.82	13.14	2.80	17.66	1.95	0.39	2.99639		
3-4	11.59	0.02	4.03	0.31	3.82	1.77	5.07	4.73	9.88	16.17	8.81	29.3039		
4-5	14.16	6.57	0.08	15.29	2.03	13.12	21.81	40.63	23.33	1.17	0.05	18.8737		
5-6	40.12	9.03	0.24	287.35	4.73	0.35	0.86	9.76	2.64	9.75	5.00	107.119		
6-7	17.91	13.15	1.83	16.85	3.76	5.17	0.89	27.78	10.39	0.64	0.71	29.6743		
7-8	656.69	0.67	0.86	1.05	15.31	0.03	2.57	0.19	1.09	1.19	1.21	85.1172		
8+	22.24	9.00	7.83	24.45	4.91	17.56	15.99	5.10	23.84	1.76	6.03	62.8036		
Sum	782.11	38.97	47.85	371.88	43.34	42.77	76.23	101.94	89.93	47.96				

Individual occurrences

Habitat Characteristics and Use

177

df=4, p=0.05

crit. val. = 9.488

Type of Vegetative Cover	TO	Turtles	HO	Habitat	TO(exp)	Chi-square
None	13	0.00	1	0.01	23	4.62 -
Floating	3019	0.96	125	0.93	2924	3.08 -
Emergent	49	0.02	4	0.03	94	21.23 <
Floating & Submerged rooted	46	0.01	1	0.01	23	21.85 >
Floating & Emergent	31	0.01	4	0.03	94	41.84 <
n=	3158		135	Sum		92.62

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Type of Vegetative Cover

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5524	TURTLE_7200	TURTLE_7201	TURTLE_7202	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	HO	Habitat %
TVC	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271		
None	1	2	2	0	1	3	0	0	3	0	1	13	1 0.01
floating	346	338	335	277	123	399	347	207	364	160	162	3018	125 0.93
emergent	19	11	0	17	2	0	0	0	0	0	0	49	4 0.03
submerged /floating	12	4	0	22	7	1	0	0	0	0	0	46	1 0.01
floating/ emergent	5	5	4	9	6	1	0	0	1	0	0	31	4 0.03
	383	360	341	325	139	364	347	207	368	160	163	3157	135
Expected TO	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All	
None	3	3	3	2	1	3	3	2	3	1	1	23	
floating	355	333	316	301	129	337	321	192	341	148	151	2924	
emergent	11	11	10	10	4	11	10	6	11	5	5	94	
submerged /floating	3	3	3	2	1	3	3	2	3	1	1	23	
floating/ emergent	11	11	10	10	4	11	10	6	11	5	5	94	
Chi-squares	1786	1789	5522	5524	7200	7201	7202	7246	7247	7270	7271	All	
None	1.19	0.17	0.11	2.41	0.00	0.03	2.57	1.53	0.03	1.19	0.04	4.61	
floating	0.21	0.07	1.17	1.90	0.25	1.43	2.06	1.23	1.59	0.95	0.81	3.02	
emergent	5.16	0.01	10.10	5.64	1.09	10.79	10.28	6.13	10.90	4.74	4.83	21.21	
submerged /floating	29.59	0.67	2.53	159.45	34.62	1.07	2.57	1.53	2.73	1.19	1.21	21.87	
floating/ emergent	3.55	3.01	3.69	0.04	0.86	8.88	10.28	6.13	9.00	4.74	4.83	41.81	
	39.70	3.92	17.60	169.45	36.82	22.20	27.76	16.56	24.24	12.80	11.71		

Individual occurrences

178

Habitat Characteristics and Use

179

df=9, p=0.05 crit. val.=16.919

% Vegetative Cover	TO	Turtles	HO	Habitat	TO(exp)	Chi-square
0-10	260	0.08	17	0.13	398	47.66 <<
>10-20	70	0.02	5	0.04	117	18.86 <
>20-30	217	0.07	6	0.04	140	41.85 >
>30-40	195	0.06	7	0.05	164	5.96 -
>40-50	486	0.15	25	0.19	585	16.70 -
>50-60	79	0.03	3	0.02	70	1.11 -
>60-70	166	0.05	4	0.03	94	56.07 -
>70-80	562	0.18	26	0.19	608	3.51 -
>80-90	254	0.08	12	0.09	281	2.54 -
>90-100	869	0.28	30	0.22	702	39.85 >
n=	3158		135		Sum	234.11

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Percent Vegetative Cover

	TURTLE_1786	TURTLE_1789	TURTLE_5522	TURTLE_5534	TURTLE_7280	TURTLE_7281	TURTLE_7282	TURTLE_7246	TURTLE_7247	TURTLE_7270	TURTLE_7271	TO	NO	NO%
%VC	1786	1789	5522	5534	7280	7281	7282	7246	7247	7270	7271			
0-10	66	43	25	10	25	27	20	15	18	4	7	260	17	0.13
>10-20	7	6	5	6	7	13	14	3	5	4	0	70	5	0.04
>20-30	53	22	22	6	9	28	26	9	15	11	16	217	6	0.04
>30-40	25	20	14	28	10	22	24	6	27	15	4	193	7	0.05
>40-50	61	52	76	46	33	47	46	31	42	34	27	483	25	0.19
>50-60	7	5	15	0	3	10	15	4	6	5	9	79	3	0.02
>60-70	13	13	36	25	4	11	11	10	13	12	18	166	4	0.03
>70-80	16	48	109	3	12	50	87	75	50	54	58	562	26	0.19
>80-90	9	35	27	3	2	45	34	15	52	19	13	254	12	0.09
>90-100	126	116	12	198	34	111	70	39	140	12	11	869	30	0.22
	383	360	341	325	199	364	347	207	368	160	163	3157	135	
Expected T	1786	1789	5522	5534	7280	7281	7282	7246	7247	7270	7271			
0-10	48	45	43	41	18	46	44	26	46	20	21	398		
>10-20	14	13	13	12	5	13	13	8	14	6	6	117		
>20-30	17	16	15	14	6	16	15	9	16	7	7	140		
>30-40	20	19	18	17	7	19	18	11	19	8	8	164		
>40-50	71	67	63	60	26	67	64	38	68	30	30	585		
>50-60	9	8	8	7	3	8	8	5	8	4	4	70		
>60-70	11	11	10	10	4	11	10	6	11	5	5	94		
>70-80	74	69	66	63	27	70	67	40	71	31	31	608		
>80-90	34	32	30	29	12	32	31	18	33	14	14	281		
>90-100	85	80	76	72	31	81	77	46	82	36	36	782		
Chi-square	1786	1789	5522	5534	7280	7281	7282	7246	7247	7270	7271	ALL		
0-10	6.55	0.12	7.50	23.37	3.21	7.74	12.85	4.70	17.33	12.94	8.91	47.59		
>10-20	3.64	4.83	4.61	3.85	0.67	0.82	0.10	2.84	5.46	0.63	6.04	18.83		
>20-30	76.04	2.25	3.09	4.94	1.29	8.64	7.26	0.80	0.11	2.13	10.58	41.92		
>30-40	1.33	0.10	0.77	7.37	1.88	0.52	2.01	2.09	3.29	5.42	2.34	5.99		
>40-50	1.39	3.23	2.62	3.34	2.05	6.18	5.19	1.40	10.89	1.87	0.34	16.98		
>50-60	0.27	1.13	7.27	7.22	0.00	0.45	6.89	0.88	0.58	0.59	7.98	1.12		
>60-70	0.34	0.51	66.37	34.53	0.00	0.00	0.05	2.44	0.40	11.12	35.92	56.13		
>70-80	45.23	6.56	28.58	56.74	8.15	5.77	6.89	30.96	6.15	17.40	22.55	3.48		
>80-90	18.42	0.28	0.36	23.20	8.68	4.94	0.32	0.63	11.37	1.61	0.15	2.53		
>90-100	19.64	16.20	53.68	219.85	0.31	11.21	0.66	1.87	41.45	15.61	17.56	39.96		
	172.76	34.41	174.84	372.79	25.44	45.47	41.41	46.30	96.18	68.54	112.38			

Individual occurrences

180



END

05-30-02

